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American Foundryman

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August
1942

Foundry Industry Achieving Goal of "One For All--All For One"

THE Foundry Industry carries the distinction of being one of the oldest of industries, if not actually the oldest. From the crudest of beginnings it has survived the rigors of the ages which at times seemed destined to destroy it.

What fact has guaranteed the permanency of that industry? The answer is Service . . . the Service that castings render to numerous other industries, whose development has been materially aided by, and in some cases utterly dependent upon the use of castings.

Armed with this realization, foundrymen have carried on over countless obstacles with tireless effort and a pioneering spirit, constantly gaining in knowledge and experience, always contributing new ideas for development. In the past, advancement has been largely the effort of individual foundries. Only in recent years did we discover that few secrets remained, if they ever existed. Today, through co-operation between groups of foundries, the tempo of progress has been greatly increased, bringing our industry to the heights it now has attained.

We are bringing this background of accomplishment with us to help us through the trying tasks ahead. Those tasks involve superhuman efforts to increase production, taking on untried new jobs, converting shops to new products, even taking the shock of curtailment to the point of suspension of operations. The industry, and the men who man it, are meeting these problems with a fortitude born of hard, practical experience.

The American Foundrymen's Association and the various Trade Associations are doing their part to help individuals and groups through technical and committee work, each in its own field of useful endeavor. There is no conflict of interest or activity. The end use is **"One For All, and All for One."**

Over the years I have come to know intimately the men in our industry and something of their accomplishments. I am proud to be even a small part of the industry, because I am proud of the ideals for which it stands, and proud of the men in it, who have worked to produce the best quality of castings for the work intended. Most of all, I am proud to know that this industry is not failing our country and will never fail it in time of need, as now.

L. C. WILSON, Vice President,
American Foundrymen's Association

L. C. WILSON, general manager, Reading Steel Casting Division, American Chain & Cable Co., Inc., Reading, Pa., has long been very active in the affairs of A.F.A. and other technical and trade associations. Member of the A.F.A. Steel Division Advisory Committee for many years, and of many other committees, he served as director in 1926-28 and was elected vice president of A.F.A. at the 1942 Annual Convention. He was recently elected vice president of the Steel Founders' Society of America

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American Foundryman

CONTENTS

August, 1942

Volume 4 **Number 8**

	Page
Foundry Industry Achieving Goal of "One for All—All for One," *by L. C. Wilson*	Inside Front Cover
A.F.A. Directors Meet, Plan Activities to Help Foundry Industry During Wartime	2
War Activities Advisory Committee Streamlines Program of Activities	4
Caterpillar Launches "Win On Work" Campaign	6
Cupola-Converter Process Data Presented at A.S.T.M. Meeting	6
The Practical Theory of Shrinkage, *by G. A. Timmons*	8
Army Ordnance Flag to Belle City Malleable for Production	15
Aid Offered Foundries in Apprenticeship Work	16
A.S.T.M. President Lundell Pays Tribute to Early Work of A.F.A.	17
A United Industry	18
The Place of Light Non-Ferrous Castings in Aircraft Production	19
A.F.A. Plant Protection Code Getting Widespread Recognition	27
New Members	28
Chapter Activities	29
Howard Foundry Wins Navy "E" for Non-Ferrous Production	31
Abstracts of Current Foundry Literature	32

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A.F.A. Directors Meet, Plan Activities to Help Foundry Industry During Wartime

MEMBERS of the A.F.A. Board of Directors gathered at the Palmer House, Chicago, July 18-19, to consider the conduct of the Association activities during the first full year of America at war. It may be generally conceded that no more important board meeting of A.F.A. has been held in a quarter century from the standpoint of number, complexity and scope of the problems facing the foundry industry today.

From the moment that President Duncan P. Forbes called the meeting to order it was plain that this board, composed of leaders of the industry from every section of the country and Canada, was realistic in its outlook. Problems of policy arising out of war conditions were thoroughly discussed, and sound recommendations made for strengthening Association activities on behalf of the entire industry.

One instance of this realistic approach was the approval given the work and recommendations of the new War Activities Advisory Committee. Some of the recommendations considered, bearing directly on the A.F.A. work during wartime, included establishing of closer contact with foundry groups in Allied countries, apprentice training in greatly expanded production plants, chapter participation in the war program, reorganization of technical activities, and formation of a new non-ferrous division in the field of aluminum and magnesium castings. Most of these subjects are reported on pages 4 and 5 of this issue.

Chapter Activities

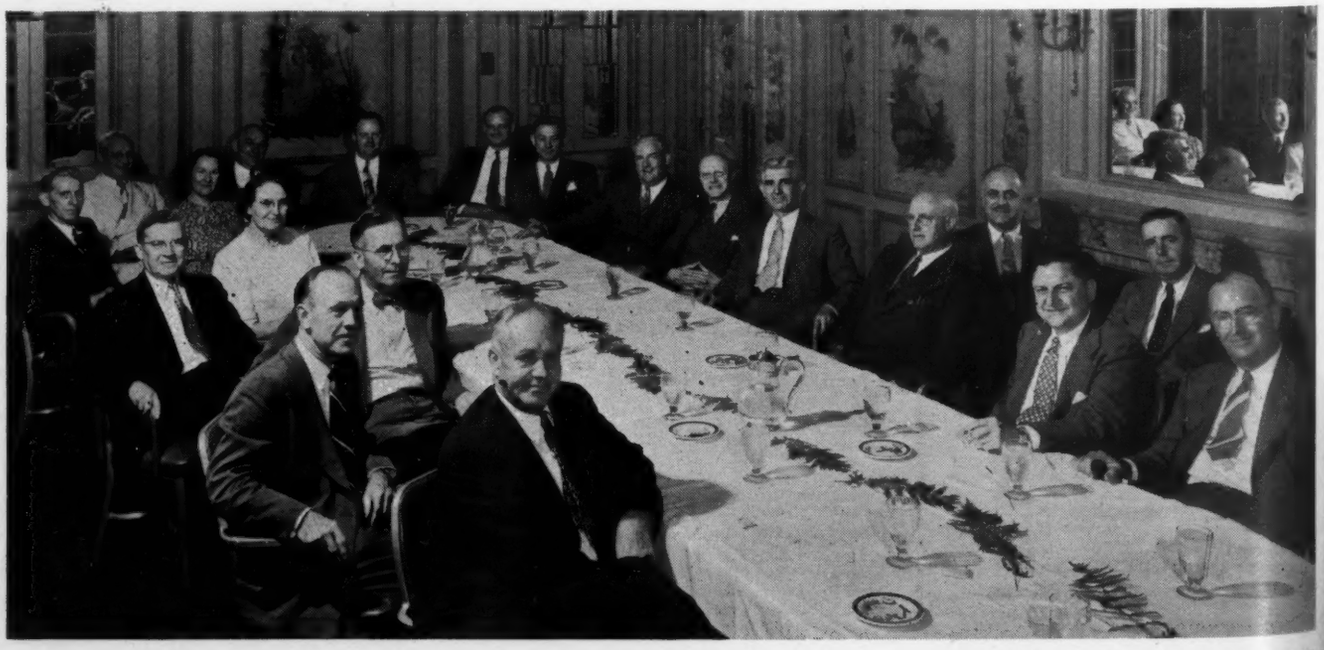
As stated in the report of Secretary R. E. Kennedy, two new chapters have joined the A.F.A. family during the past year, these being the Toledo chapter, and the Eastern Canada-Newfoundland chapter. Possibilities of other chapters being organized in the months ahead also were presented.

It is estimated that attendance at regular chapter meetings this past year was about 30,000, representing a substantial increase over the previous year. A number of chapters sponsored lecture courses, regional conferences and special outings, all of which proved outstandingly successful. The recommendation was made that educational courses be continued in the year ahead, as being of special value at this time.

Record Membership

In reporting on A.F.A. affairs for the year 1941-42, Executive Vice President C. E. Westover announced that as the result of the "5,000 in '42" membership campaign, initiated late last fall,

Leaders of the foundry industry, members of the A.F.A. Board of Directors, in session July 19 at the Palmer House, Chicago. Directors and guests, left to right around the table: H. S. Washburn, Plainville Casting Co., Plainville, Conn.; Vice President L. C. Wilson, Reading Steel Casting Div. of American Chain & Cable Co., Inc., Reading, Pa.; R. J. Allen, Worthington Pump & Machinery Corp., Harrison, N. J.; C. E. Hoyt, A.F.A. Manager of Exhibits; Miss Jennie Reininga, A.F.A. Assistant Treasurer; H. S. Simpson, National Engineering Co., Chicago; R. E. Kennedy, A.F.A. Secretary; Miss P. Mockler, A.F.A. Chicago Staff; M. J. Gregory, Caterpillar Tractor Co., Peoria, Ill.; President D. P. Forbes, Gunite Foundries Corp., Rockford, Ill.; N. F. Hindle, A.F.A. Assistant Secretary; B. D. Claffey, General Malleable Corp., Waukesha, Wis.; Vaughan Reid, City Pattern Works, Detroit; Harold J. Roast, Canadian Bronze Co., Ltd., Montreal, P. Q.; J. E. Crown, U. S. Naval Gun Factory, Washington, D. C.; J. G. Coffman, Los Angeles Steel Casting Co., Los Angeles, Calif.; C. E. Westover, A.F.A. Executive Vice President; L. N. Shannon, Stockham Pipe Fittings Co., Birmingham, Ala.; I. R. Wagner, Electric Steel Castings Co., Indianapolis, Ind.; S. V. Wood, Minneapolis Electric Steel Castings Co., Minneapolis, Minn.



that goal was reached and passed on June 30th. On that date membership in A.F.A. totaled 5,047, a new all-time high, a net gain of over 17.4 per cent over membership a year ago. Of the total, 4,283 or approximately 85 per cent are members in chapter territories, with 605 outside of chapter in this country.

A.F.A. membership by classes is shown in the following table:

Honorary and Life	53
Sustaining	104
Company	1182
Personal	774
Personal-Affiliate	2479
Personal-Associate	214
Student	28
Apprentice	54

Apprenticeship Work

Since one of the most urgent problems of the foundry industry today involves training of workers, it was recommended that the work of the Apprentice Training Committee be continued. Great emphasis was placed, however, on the question of short-time training because of immediate demands of our war production program.

The Directors also recommended that the national apprenticeship contests, sponsored for many years by A.F.A., be continued. Great interest in these contests has been aroused among local foundry plants.

Publications

The publications program submitted by Assistant Secretary N. F. Hindle was substantially approved, especially those publications having a direct bearing on the foundry war effort. A booklet containing papers to be presented at the 1943 Symposium on *Graphitization of White Cast Iron* now is being prepared. The lectures on *Fundamentals of Sand Shop Control,* scheduled for presentation at the 1942 convention but unavoidably canceled, are to be prepared in book form. These lectures are the work of W. G. Reichert, American Brake Shoe & Foundry Co., Mahwah, N. J.

Plans are developing for revision of the *Cast Metals Handbook,* also the book covering *Testing and Grading of Foundry Sands.* It was decided that *Recommended Non-Ferrous Castings Practices* should be revised and republished, and the manual of Cupola Operation and Theory, a part of the Cupola Research Project, also came in for discussion.

A.F.A. affairs being conducted on a budget basis, a budget covering all estimated 1942-43 expenditures, including all publications, was submitted by C. E. Westover, and approved by the Directors.

I.B.F. Greetings

For many years A.F.A. has cooperated closely with the Institute of British Foundrymen, resulting in an exchange of papers carried on continuously for over twenty years. This cordial relationship was further shown at the board meeting when a cablegram from the I.B.F. was read, datelined during their recent annual meeting in London, with the following message: "Institute British Foundrymen in annual conference send cordial greetings and join with you in working for speedy and victorious conclusion to our united efforts. (Signed) Miles, President; Makemson, Secretary."

1943 Convention

C. E. Hoyt, Convention and Exhibits Manager, presented a report covering the recent Cleveland meeting, with its splendid exhibit and record attendance in spite of existing conditions. In connection with the 1943 convention, the selection of a date, place and type of meeting was referred to the Executive Committee for later action.

In connection with next year's convention the selection of W. G. Reichert as the lecturer for the 1943 lecture course was unanimously approved. Similar approval was given the recommendation that the honor of presenting the first annual awards technical lecture be bestowed on John W. Bolton, Lunkenheimer Co., Cincinnati, Ohio.

D. B. Claffey (left) admires the plaque presented by Director friends to Past President H. S. Simpson, while Mr. Simpson looks proudly on.

Three A.F.A. leaders in conversation at the recent Board of Directors meeting. Left to right—Executive Vice President C. E. Westover, President D. P. Forbes, and Vice President L. C. Wilson.

Two U. S. Papers Before Annual I.B.F. Meeting

FEATURING the annual meeting of the Institute of British Foundrymen, held June 20 in London, England, was the presentation of the Edward Williams lecture paper on "Foundry Teamwork," prepared on invitation by Dr. H. W. Gillett, Battelle Memorial Institute, Columbus, Ohio. In the absence of the author, A.F.A. medalist of 1932, the paper was read by J. G. Pearce, director of the British Cast Iron Research Association, and was well received, according to report of the meeting received from Vincent Delport, European representative of A.F.A.

Another interesting paper presented at the meeting was the annual exchange paper of A.F.A., by Carl F. Joseph, Saginaw Malleable Iron Division of General Motors Corp., Saginaw, Mich. Mr. Joseph's paper, dealing with "Production of Arma Steel Castings," was presented for the author by A. E. Peace, Ley's Malleable Castings, Ltd., who is chairman of the Institute's subcommittee on malleable iron.

For many years A.F.A. has maintained exchange paper relationships with many foreign foundry associations. The 1942 exchange paper from the I.B.F., presented at the recent Cleveland convention, covered "Production of Uniform Steel for a Light Castings Foundry," by C. H. Kain and L. W. Sanders, Lake & Elliott, England.

War Activities Advisory Committee Streamlines Program of Activities

PRIOR to the meeting of the A.F.A. Board of Directors on July 18-19, the important War Activities Advisory Committee met in Chicago July 13 to consider further recommendations involving Association activities during wartime. This committee, formed by President Duncan P. Forbes, shortly after taking office this year, has already put forth some excellent proposals for correlating committee work more closely with the war program.

Serving with President Forbes on the committee are four men who have long been identified with A.F.A. and have done much to promote technical advancements in the industry. They are Fred J. Walls, H. Bornstein, F. A. Melmoth, Wm. Romanoff. All of them have served on many

Vincent Delport

A.F.A. committees over a long period of years.

Wartime Committeemen

Fred. J. Walls, International Nickel Co., Detroit, is chairman of the Gray Iron Division; chairman, Committee on Welding Cast Iron, and served as chairman of the 1941-42 Committee on Program and Papers of the Gray Iron Division, as well as chairman of the Technical Activities Correlation Committee. Mr. Walls was a director of A.F.A. in 1939-42.

H. Bornstein, Deere & Co., Moline, Ill., is a past president of A.F.A. (1937-38), a past chairman of the Quad City chapter, past chairman of the Gray Iron Division, and has been active on numerous committees of both the Gray Iron and Malleable Iron Division for years.

F. A. Melmoth, Detroit Steel Casting Co., Detroit, is a past chairman of the Steel Division, and has served on a number of committees of that division, as a member of the Advisory Committee of the Foundry Sand Research Committee, and is an A.F.A. medalist (1940). He is at present chairman of the Detroit chapter.

F. G. Steinebach

Wm. Romanoff, H. Kramer & Co., Chicago, has had broad experience in non-ferrous affairs of A.F.A. He is chairman of the Non-Ferrous Division, and member of the Cast Metals Handbook Revision Committee, Program and Papers Committee, and the Recommended Practices Committee of that division.

Foreign Contacts

In view of the importance of maintaining close contacts with our Allies in the war, steps were taken to broaden present A.F.A. contacts with foreign foundry groups. Frank G. Steinebach, *The Foundry*, Cleveland, who has been chairman of International Relations Committee for several years, will continue, as will Vincent Delport, Penton Publishing Co., London, England, as A.F.A. European representative. In addition, Dr. Miguel Siegal, Instituto des Pesquisas Technologicas, Sao Paulo, Brazil, who presented a paper on foundry practice in Brazil at the 1942 convention, becomes the official A.F.A. representative in that country. Wm. A. Gibson, foundry consultant of Sydney, Australia, was appointed official representative for the Association in the "land down under."

General Interest Group

Another important action of the War Activities Committee was to thoroughly review the technical committee organization, with a view to clarifying some committee designations. Thus, it was decided that a new group would be formed, comprised of all committees whose activities are of a general interest. A chairman will be appointed by President Forbes.

Two Non-Ferrous Groups

Steps also are being taken to expand the present Non-Ferrous Division into two separate divisions, one to be known as the Brass and Bronze Division, the other the Aluminum and Magnesium Division. This was felt desirable because of increasing

Miguel Siegal

interest in non-ferrous matters and enormous expansion of aluminum and magnesium castings production, involving virtual creation of a new magnesium castings industry. Mr. Romanoff, present chairman of the Non-Ferrous Division, will head the new Brass and Bronze group, and a chairman will be appointed by President Forbes to lead the new light alloys group.

Cost Committee

The costs of chemical and physical tests required in meeting Government specifications will be studied by the Cost Committee, with the object of issuing information on this important wartime subject. The Cost Committee was one of the first A.F.A. committees ever organized, and recently published a comparison of cost factors in the various

branches of the castings industry.

Foundry Training

Several phases of the foundry training problem now facing the industry were discussed at length. The Apprentice Training Committee is continuing its long-time training work, but will devote considerable thought to special short-time war training, in view of the great number of new workers now entering all industry. The need for skilled supervisory personnel was brought out, leading to a recommendation that the Foreman Training Committee program emphasize aid to smaller plants, particularly in their foreman training problems.

Both of these groups have done yeoman service for many years, the apprentice committee being one of the first organized. Today, all phases of training are particularly valuable to the industry.

Cupola Research

Work of the Cupola Research Project Steering Committee was reviewed at the July 13 meeting, and the important activities of this group highly praised. The committee, headed by D. J. Reese, International Nickel Co., New York, has a three-point program of reviewing published literature on the cupola, co-ordinating known data and publishing a handbook, and conducting research work. Several hundred foundries and foundry equipment and supply firms have already enthusiastically supported the project.

Shop Control Book

One of the features scheduled for the 1942 convention was a shop course on the "Fundamentals of Sand Shop Control," which W. G. Reichert, American Brake Shoe & Foundry Co., Mahwah, N. J., was to have conducted. When Mr. Reichert found it impossible to attend the course was cancelled, and it now is intended to prepare and publish the course lectures in book form. The Sand Shop Course Committee and other committees also are preparing correlated abstracts on foundry literature, for ready reference during the present emergency.

The Sand Control book will supplement that on "Testing and Grading Foundry Sands." Where the latter deals with procedures and instruments for testing, the shop control book will provide a practical application of the information so gained, for everyday foundry practice. Mr. Reichert has long been interested in sand work, and now is in charge of sand operations in some forty foundries of his company, including steel, gray iron and non-ferrous sand practice.

Chapter Work

The work of A.F.A. chapters likewise is being tied in more closely with the war effort, through appointment of a War Problems Committee within each chapter. These committees will advise local foundries on their war production problems, with particular attention to the conversion of plants to war production as rapidly as possible.

Non-Ferrous Alloys

Another important recommendation of the War Activities Committee was for the publication by A.F.A. of a book of recommended practices on non-ferrous alloys. This book will cover aluminum and magnesium castings practices as well as brass and bronze, thus covering the work of both of the two new non-ferrous groups formed from the previous Non-Ferrous Division. It is to be published as quickly as possible, the goal of the committee from the first.

Cast Iron Compression Test Specimens Adopted

WHILE the compressive strength of cast iron has long been recognized as one of its most favorable qualities, little recorded information on that property appears to be available. This may have been due partly to the fact that no recognized specimen for testing cast iron in compression was available.

For the information of those interested in the compression strength of cast iron, A.S.T.M. at its recent meeting adopted as tentative a method of compression testing cast iron and has prescribed specimen sizes. Two specimens are prescribed: (1) 0.798±0.01-in. in diameter and 2⅜-in. long for determining compressive strength, and (2) a specimen of same diameter but 6⅜-in. long for determining the modulus of elasticity in compression.

A.F.A. Staff Member Now Ensign in Navy

GERALD K. BUHLER, for the past five years a member of the A.F.A. Headquarters Staff, recently was commissioned an Ensign in the U. S. Navy and now is in the service, Naval Ordnance Branch. Early in July he completed his indoctrination training at Notre Dame University, South Bend, Ind., and now has been assigned to further duties.

Gerald K. Buhler

"Jerry" joined the A.F.A. Staff in 1937 and was closely identified with the publishing of the *American Foundryman*, the quarterly *Transactions*, and other Association publications. He is known to many foundrymen through his work at the past five national conventions, especially in connection with the technical sessions. When the Non-Ferrous Founders Society was organized, he served as acting secretary until a permanent secretary had been appointed.

The A.F.A. Staff joins with his many friends in the industry in wishing Ensign "Jerry" Buhler the *Best of Luck!*

Caterpillar Launches a "Win on Work" Campaign

IN LINE with the recent request of Donald M. Nelson, W.P.B. chief, for increased war production, in some 2,000 plants throughout the country, many firms have already set up the necessary machinery for doing the job in their own shops. One of these firms is Caterpillar Tractor Co., Peoria, Ill., who recently announced the opening of an intensified "Win on Work" drive to carry on greater production in that plant.

A joint Labor-Management War Production committee first was appointed, aimed at increasing the efficiency of tools, machines, materials and manpower. Eight objectives for the drive were set, as follows: (1) Conserve tools and materials; (2) keep fit, work safely; (3) be on time every day; (4) cut lost machine time; (5) co-operate; (6) keep informd about the company's war effort; (7) mobilize ideas for boosting production; (8) produce more for Victory.

A study of plant efficiency has been initiated, suggestions for increasing production are encouraged, and bulletin boards and posters prepared. In announcing the drive, a special tabloid size house organ, called "Win on Work," has been published containing news of the campaign and information about the company product calculated to stimulate greater employee effort. The company, long an A.F.A. member, is heavily engaged in producing materials for our war program.

A. K. Reading, Long a Steel Foundryman, Dies

A. K. READING, chief industrial specialist for the Metals Division of the War Production Board, died suddenly in Washington July 8, at the age of 59. Appointed to W.P.B. last October, where his duties were closely connected with Government requirements for steel castings, he previously served as general manager, Zimmerman Steel Co., Davenport, Iowa, from 1919 until his resignation in 1940.

For many years Mr. Reading was active in the foundry and metallurgical industries. An active member of A.F.A. and the Quad City Chapter, he also was a member of the American Society for Steel Treating, and served at one time as vice-president of the Steel Founders Society of America.

A native of Davenport, he graduated from Purdue University, Lafayette, Ind., in 1906. Thereafter he was associated with the American Car & Foundry Co., served as assistant editor of Popular Mechanics magazine, and was connected with the Bettendorf Co., Bettendorf, Iowa, from 1908 to 1919. Mr. Reading was well known in the steel industry.

Cupola-Converter Process Data Presented at A.S.T.M. Meeting

USE of the cupola-converter method for greater production of steel was advocated by C. E. Sims and F. B. Dahle, Battelle Memorial Institute, Columbus, Ohio, in a paper presented before the annual meeting of the American Society for Testing Materials at Atlantic City, N. J. The paper, "Comparative Quality of Converter Cast Steel," should be of interest to members of the steel foundry industry.

The report was based on a research investigation of cast steels conducted in the laboratories of the Battelle institute, and was sponsored by the Whiting Corporation, Harvey, Ill. The importance of cast steel in the war production was indicated by its use for airplane landing gears, gun mounts, tanks and other ordnance materiel. The authors stated that cast steel armor plate has stood up well under ballistic tests.

Early Bessemer steel was relatively impure and unrefined and therefore inferior in some engi-

TABLE I.—CHEMICAL ANALYSES OF GRADE "B" CAST STEELS.

Steel	Carbon, per cent	Manganese, per cent	Silicon, per cent	Phosphorus, per cent	Sulfur, per cent	Residual Metals: Copper, per cent	Residual Metals: Chromium, per cent	Residual Metals: Nickel, per cent	Residual Metals: Molybdenum, per cent	Residual Metals: Nitrogen, per cent	Special Deoxidizers Added to Ladle, lb. per ton: Al	Fe Ti	Ca Si	Ca Si Mn
Acid Open Hearth Steels														
493	0.21	0.69	0.42	0.030	0.035	0.11	0.05	0.01	0.006	0.006	...	2	3	...
509	0.24	0.66	0.47	0.036	0.035	0.12	0.04	0.01	0.006	0.005	...	2	3	...
F-1	0.33	0.67	0.36	0.036	0.036	0.05	0.02	0.04	0.060	0.005	...	...	...	...
F-2	0.30	0.85	0.37	0.035	0.033	0.04	0.02	0.04	0.051	0.006	...	...	...	...
Basic Open Hearth Steels														
9551	0.27	0.58	0.46	0.013	0.025	0.15	0.14	0.06	0.016	0.005	...	...	...	...
9567	0.27	0.68	0.45	0.019	0.034	0.10	0.12	0.05	0.012	0.005	...	...	...	...
O-1	0.32	0.72	0.34	0.017	0.027	0.12	0.05	0.15	0.04	0.004	...	...	...	...
O-2	0.30	0.77	0.34	0.016	0.029	0.12	0.06	0.17	0.03	0.004	...	...	...	...
Acid Electric Steels														
715	0.27	0.80	0.45	0.027	0.034	0.06	0.05	0.03	0.013	0.008	...	3	...	3
724	0.26	0.72	0.39	0.026	0.036	0.08	0.03	0.06	0.009	0.008	...	3	...	3
1009	0.26	0.68	0.40	0.034	0.038	0.11	0.06	0.18	0.038	0.010	...	4	...	1.5
1025	0.24	0.66	0.39	0.035	0.040	0.11	0.06	0.16	0.034	0.009	...	4	...	1.5
1163	0.26	0.68	0.49	0.036	0.037	...	...	...	...	0.009	2	...	...	...
Basic Electric Steels														
E-1	0.34	0.88	0.28	0.033	0.035	0.12	0.19	0.43	0.06	0.007	0.7	...	...	...
Converter-Acid Electric Steels (Triplex)														
H-30	0.30	0.73	0.40	0.029	0.035	0.36	0.04	0.08	0.056	0.011	2[a]	...	2	...
H-34	0.34	0.78	0.40	0.033	0.036	0.39	0.04	0.06	0.062	0.011	2[a]	...	2	...
H-38	0.33	0.58	0.31	0.023	0.041	0.38	0.03	0.08	0.005	0.012	2[a]	...	2	...
H-42	0.35	0.73	0.35	0.059	0.047	0.43	0.03	0.10	0.004	0.010	2[a]	...	2	...
Converter Steels														
1	0.26	0.77	0.55	0.034	0.041	0.19	0.04	0.09	0.008	0.008	2	...	...	...
2	0.26	0.66	0.38	0.032	0.027	0.09	0.04	0.06	0.006	0.009	2	...	...	...
3	0.27	0.65	0.37	0.038	0.026	0.09	0.05	0.06	0.007	0.009	2	...	...	...
4	0.26	0.50	0.32	0.033	0.028	0.14	0.03	0.05	0.007	0.009	2	2	...	...
A	0.29	0.50	0.33	0.040	0.031	0.09	0.02	0.085	0.008	0.006	1	...	...	...
B	0.33	0.85	0.43	0.043	0.035	0.09	0.02	0.072	0.018	0.008	1	...	...	...
C	0.33	0.64	0.39	0.049	0.038	0.10	0.03	0.079	0.018	0.007	1	1.7	...	...
D	0.29	0.73	0.36	0.044	0.035	0.09	0.03	0.077	0.014	0.007	2.25	...	...	...

[a] Aluminum added to electric furnace in these heats.

TABLE II.—MECHANICAL PROPERTIES OF GRADE "B" CAST STEELS.

NOTE.—Tensile values and Charpy impact values are averages of duplicate tests. Izod values are averages of three tests.

Steel	Yield Strength, psi.		Tensile Strength, psi.		Elongation, per cent		Reduction of Area, per cent		Brinell Hardness As Normalized and Drawn	Impact Strength As Normalized and Drawn, ft-lb.		A.S.T.M. Grain Size Normalized and Drawn	Type of Sulfide Inclusions
	As Normalized	As Normalized and Drawn	As Normalized	As Normalized and Drawn	As Normalized	As Normalized and Drawn	As Normalized	As Normalized and Drawn		Izod	Charpy		
ACID OPEN HEARTH STEELS													
493	49 000	46 500	74 500	74 500	33.5	32.0	57.0	55.5	147	34	25	7 to 8	I
509	46 000	43 000	75 000	75 000	33.0	34.0	57.0	56.5	142	32	24	7 to 8	I
F-1	46 500	46 000	84 000	83 000	28.0	29.0	47.0	46.5	162	22	18	6 to 7	I
F-2	49 000	47 500	86 500	87 000	29.5	29.0	49.5	49.5	169	22	18	6 to 7	I
BASIC OPEN HEARTH STEELS													
9551	45 000	45 500	74 000	75 500	29.0	33.0	38.0	56.5	144	40	27	6 to 7	I
9567	46 000	46 000	78 000	79 500	31.5	32.5	56.5	57.0	150	36	26	7	I
O-1	48 500	46 500	82 500	81 500	31.0	31.5	52.5	52.5	162	34	22.5	7	I
O-2	47 500	48 000	80 000	80 500	32.0	33.0	53.5	55.5	157	29	24	6 to 7	I
ACID ELECTRIC STEELS													
715	56 000	48 000	83 000	81 000	28.5	28.5	49.0	49.5	165	28	20	8	I
724	52 500	47 500	80 000	80 000	30.5	30.0	54.0	54.0	157	29	23	8	I
1009	50 500	49 000	82 500	82 000	29.0	30.0	53.0	52.0	162	25	20	7	I
1025	47 000	47 000	78 500	78 500	32.0	30.5	53.0	54.5	155	27	21.5	7	I
1163	47 000	46 000	75 000	75 000	27.0	29.0	40.0	45.0	142	...	22	7 to 8	III
BASIC ELECTRIC STEELS													
E-1	59 000	60 500	92 000	93 500	20.0	23.0	26.5	33.0	188	19	12	7 to 8	II
CONVERTER-ACID ELECTRIC STEELS (TRIPLEX)													
H-30	58 500	53 500	84 500	87 000	28.0	26.0	44.5	35.5	170	34	19	8	III
H-34	58 000	55 500	87 500	87 500	25.5	24.5	35.0	37.0	174	33	18.5	8	III
H-38	47 500	47 500	81 000	81 000	20.0	24.0	29.0	33.5	157	27	15	6 to 8	III
H-42	61 000	55 500	90 000	91 500	23.0	23.5	32.0	30.0	176	21	13	8+	III
CONVERTER STEELS													
1	53 000	53 500	80 500	81 000	29.5	31.0	45.0	49.5	155	38	21	8	III
2	47 500	46 000	74 500	75 000	28.0	33.0	42.5	55.5	146	44	28	8	III
3	48 500	48 000	76 500	77 500	27.0	31.0	44.5	53.0	152	42	26	7 to 8	III
4	47 000	47 000	72 500	73 500	29.0	31.0	47.0	50.0	143	43	25.5	8	III
A	46 000	44 500	77 000	76 500	28.0	31.5	40.5	52.0	148	28	23	7	III
B	59 500	58 500	87 500	88 000	19.0	24.0	22.5	34.5	172	26	13	8	II
C	55 500	55 000	85 500	85 000	22.5	23.5	32.0	31.0	168	30	13	8	II
D	52 000	50 000	81 000	80 000	27.0	30.0	47.0	48.5	157	39	23.5	7 to 8	III

neering qualities. By use of the modern cupola with the converter, the authors stated, cast steel can be made to the same chemical composition as acid open-hearth or acid electric cast steel. Data presented in the report tend to prove that properly made converter steel has engineering qualities on a par with steels made by other processes.

Tests Reported

The author's data showed that the room temperature mechanical properties of all the types of steel tested were entirely orthodox for grade B cast steel and varied with the composition and type of inclusions, without regard to the method of manufacture. Likewise, low impact properties were found to be dependent upon deoxidation practice. Where low-temperature toughness is required, as in mobile equipment used in cold climates, it was suggested that the steel be judged on performance tests.

Chemical analyses of Grade B cast steels tested are shown in Table 1, mechanical properties in Table 2, and low-temperature impact properties in Table 3.

Sub-Committee Formed

Following the report, recommendation was made that a subcommittee be formed to further investigate the possibilities. Committee 22 of A.S.T.M. A-1 on specifications for application of steels for high-temperature purposes has since appointed a sub-committee to study the problem of whether or not steel made by the converter process should be included in the specification. As it now reads, the specification states that metal for such application "shall be produced by the open-hearth or electric furnace process or any process agreed upon by the manufacturer and the consumer."

In discussion of the paper at Atlantic City, attention was called to the fact that data are given in Table 3 for only one heat of electric basic steel, criticism being made that the properties of basic electric steel thus were judged on the basis of one heat.

TABLE III.—LOW TEMPERATURE IMPACT PROPERTIES OF GRADE "B" STEELS.

Steel	Type of Sulfide Inclusions	Single-Width Charpy (Keyhole Notch) Impact Strength, ft-lb.															
		212 F.		70 F.		32 F.		0 F.		−20 F.		−40 F.		−60 F.		−80 F.	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
ACID OPEN HEARTH STEELS																	
493	I	30.5	30.0	27.5	23.0	22.5	21.5	21.0	20.0	19.5 *	3.5	17.0	2.5	2.0	2.0	....	....
509	I	32.5	32.5	24.5	24.0	18.5	18.5	22.5 *	5.5	20.0	4.0	17.0	2.0	2.0	2.0	....	....
F-1	I	22.0	21.5	19.5	16.5	13.5	12.5	14.5 *	7.0	8.0	2.0	3.0	1.0	1.5	1.5	....	....
F-2	I	....	....	18.0	17.5	16.0	14.5	14.0	13.0	12.0 *	3.0	2.0	1.5	1.0	1.0	....	....
BASIC OPEN HEARTH STEELS																	
9551	I	34.5	32.0	27.5	27.0	23.0	22.0	23.0	22.0	20.5	20.0	16.5 *	3.5	18.0	3.0	....	....
9567	I	34.5	34.0	27.0	25.0	22.0	22.0	21.0	21.0	21.5	19.5	18.0 *	2.5	10.0	2.0	....	....
O-1	I	....	....	24.5	20.5	18.0	12.0	16.0	16.0	17.0 *	4.5	5.0	2.5	2.0	2.0	....	....
O-2	I	28.5	28.5	25.0	22.5	21.0	20.5	15.5	14.0	13.0 *	3.5	3.0	2.5	....	....	....	....
ACID ELECTRIC STEELS																	
715	I	29.0	26.5	20.0	19.5	21.5	18.0	14.5 *	4.0	19.0	2.0	2.0	2.0	....	....	....	....
724	I	27.0	26.0	24.0	22.0	19.0	16.0	18.5	18.0	15.0 *	3.5	2.0	2.0	....	....	....	....
1009	I	25.0	24.5	21.5	18.0	14.0	13.0	15.0 *	5.0	10.0	2.5	7.5	1.0	1.0	1.0	....	....
1025	I	27.0	26.0	22.5	20.5	15.5	13.5	19.0	17.5	16.0	14.0	9.0 *	1.0	1.0	1.0	....	....
1163	III	23.0	19.5	23.5	21.0	20.0	19.0	17.5	16.5	15.5	15.0	12.5	11.5	13.5	8.5	9.5 *	2.0
BASIC ELECTRIC STEELS																	
E-1	II	15.0	13.5	12.5	12.0	10.0	10.0	7.5	7.0	6.5	5.0	6.5	6.0	3.5	2.5	....	....
CONVERTER-ACID ELECTRIC STEELS (TRIPLEX)																	
H-30	III	22.0	20.0	19.5	18.5	18.5	17.0	12.5	11.5	10.0	9.5	10.5	9.0	15.5	11.0	....	....
H-34	III	....	....	19.0	18.0	13.0	11.5	16.0	11.0	10.5	9.0	13.5	8.5	9.0	8.5	....	....
H-38	III	18.0	14.0	16.0	14.5	13.0	12.0	10.5	10.0	11.5	10.0	10.5	10.0	9.0 *	5.0	6.5	5.5
H-42	III	....	....	14.0	12.5	10.0	9.0	9.5	7.0	12.5	12.0	14.0	6.5	5.0 *	4.0	3.0	2.0
CONVERTER STEELS																	
1	III	24.0	21.0	22.5	20.0	20.0	18.0	14.5	14.0	17.0	16.0	14.5	12.5	15.5	15.0	12.0	12.0
2	III	32.0	30.0	27.5	27.0	25.0	24.0	23.0	23.0	21.0	20.5	19.5	17.5	18.0	16.0	14.5	14.5
3	III	30.0	30.0	26.0	25.5	25.0	23.0	24.0	20.5	20.0	18.5	18.5	13.5	18.0	17.5	17.0	14.5
4	III	30.0	29.5	26.0	25.0	22.0	18.5	21.5	21.0	19.5	17.5	16.0	11.0	17.0	15.5	15.5 *	9.0
A	III	22.0	22.0	24.0	21.5	....	....	16.0	14.5	16.5 *	9.5	11.0	5.0	10.0	8.5	5.5	3.5
B	II	....	....	13.5	12.0	10.0	10.0	9.5	9.0	7.5	7.0	5.0 *	4.5	7.0	5.5	2.5	2.0
C	II	13.0	13.0	13.0	12.5	10.0	10.0	14.0	7.5	10.0 *	4.5	3.5	2.5	4.5	2.0	2.0	1.5
D	III	....	....	23.5	23.5	18.0	15.0	16.0	11.5	12.5	11.5	11.5	11.5	13.0	9.5	7.5 *	5.0

* Asterisk placed in data at temperature where low or erratic results were first encountered.

The Practical Theory of Shrinkage in Gray Cast Iron†

By G. A. Timmons,* Detroit, Mich.

The author has excellently outlined theoretically and demonstrated with practical tests, many of the reasons for the occurrence of shrinkage cavities in gray iron. He explains first the characteristic appearance of such cavities, as well as sponginess, and then explains the causes and factors which influence that defect. Of special interest are the tests conducted to determine the percentage voids in 4-in. cube castings. He concludes his discussion with five recommendations on how shrinkage tendencies may be decreased.

THE term "shrinkage" has at least two interpretations to the gray iron foundryman. The first interpretation considers the total volume change which occurs over the temperature range between pouring temperature and room temperature. While the iron is completely liquid, the entire mold is filled, but after the iron has solidified and cooled to room temperature the casting is smaller than the mold due to a slight contraction which has taken place. This phenomenon is readily understood and the volume change is anticipated by the foundryman who makes his pattern and mold sufficiently oversize to account for the contraction, and thereby holds his dimensions to the desired tolerances. The second interpretation of the term "shrinkage" is concerned with a type of defect often found in gray iron castings which is also referred to as "porosity," "sponginess," "voids" or "draws." The topic of this discussion is this second interpretation.

The various factors which influence this type of shrinkage will be discussed to provide a clearer understanding of the problem so that it can be dealt with on a sound basis, enabling the foundryman to exercise as much control over its occurrence as possible, thus reducing to a minimum rejections due to its presence.

Occurrence of Shrinkage Defects

Shrinkage or porosity occurs in castings as irregular shaped cavities, or groups of cavities. They are generally characterized by the presence of dendritic crystals on the interior surfaces of the cavities or a series of interdendritic voids within a certain localized area. Such defects are usually found near the centers of heavy sections or near a change in section size. Occasionally they are found in thin, interior wall sections of such complicated castings as engine blocks or pumps. In such castings, they frequently are hidden until after the casting has been partially machined.

Many castings may contain such porous volumes, but in numerous cases, these defects occur in sections which are not subjected to high stresses or where the part is responsible for the confinement of some liquid or gas under pressure. Again, the defects may occur in locations where they are later completely removed by machining. In such cases, they are of no immediate concern to the foundryman. But when shrinkage or porosity occurs in pump castings or air compressor cylinders, in the oil line of an engine block, or near the highly stressed rim of a flywheel, it is the source of considerable consternation and every effort must be expended to eliminate it.

Causes of Shrinkage

Shrinkage is a direct result of contraction of the metal upon changing from the liquid state to the solid state when there is insufficient metal to feed the defective location. Such a condition exists whenever a volume of liquid metal is trapped within a mass of solid iron. When this occurs, no feeding can take place, since there is an insufficient quantity of molten metal to satisfy the volume contraction which results from the solidification of the entrapped liquid. Usually when the volumes of entrapped liquid iron are small, the original austenite dendrites, which are the first crystals to form from the liquid iron when the liquidus temperature is attained, grow out from the walls of solid metal and build up an intermingled framework. When the eutectic starts to freeze, there is not enough metal to fill all the interstices of the dendrites and, due to gravity, the eutectic filters to the bottom where it solidifies, leaving voids around the dendrites at the top. Figure 1A illustrates this condition in a gray iron casting. Note the voids surrounding the dendrites, cross sections of which are shown in the photomicrograph.

If a large quantity of molten metal is forced to solidify within the confines of the solid mass of metal, a cavity may result with its walls lined with dendrites which were formed while the liquid metal was in contact with the wall and which were left in an incomplete condition as the molten pool receded toward the bottom due to gravity and the contraction associated with solidification. (Figs. 1B and 1C.)

The Problem

The problem, then, is chiefly one of "feeding." If adequate heads or risers could always be provided for all sections of a casting to insure a sufficient reservoir of liquid metal which could satisfy the contraction taking place during solidification, or if all sections could be so designed that they would freeze from the bottom upward, the difficulty of porosity or shrinkage would never occur. Risers and heads are valuable in

*Metallurgist, Climax Molybdenum Co.

†Presented before the Gray Iron Division Shop Operating Course, 1942 Annual Convention.

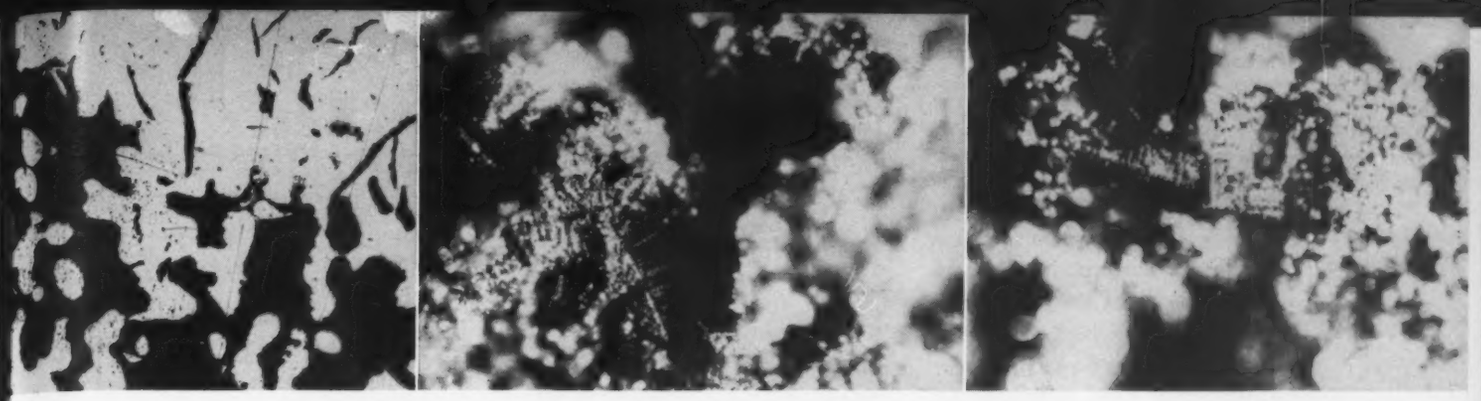


Fig. 1A (left)—Shrinkage defect where the eutectic has a sufficiently low solidification point that it has drained through the interstices of the dendrites before it solidified, leaving voids in the casting. Fig. 1B (center)—Dendrites formed in contact with the mold wall but from which the molten metal receded before it solidified, leaving a void. Fig. 1C (right)—Another illustration of the phenomena shown in Fig. 1B.

reducing or completely eliminating shrinkage in sections of a casting to which they may be joined. It is imperative, however, that the risers or the heads and the necks connecting these accessories be of sufficient cross-section that they will freeze after the casting has completely solidified. Too often, these parts freeze before the casting, making the head or riser useless as a source of supply for molten metal.

Factors Influencing Shrinkage

The formation of voids or porous sections in a casting is apparently related to a number of factors, some of which are immediately apparent and some of which are not completely understood. The following apparent factors can be considered to appreciably influence the phenomenon of porosity or shrinkage in a gray iron casting:

(1) The change of density, or its reciprocal, specific volume, as the molten iron cools from the pouring temperature to the solidus temperature.
(2) The eutectic temperature of the composition dealt with and the temperature at which solidification normally begins.
(3) Temperature gradients within the casting.
(4) The positions of gates and risers to feed the casting.

The first two factors are substantially dependent upon the composition of the iron. The last two are dependent upon the design of the casting, the construction of the mold and the pouring temperature.

The most direct cause of shrinkage cavities, or sponginess, in a gray iron casting is the change in the density of the iron as it cools from the pouring temperature to the solidus. This change in density has been studied by Saeger and Ash[1], who contributed the following quantitative information in the conclusions of their paper:

> "The coefficient of volume shrinkage in the liquid state for the irons over the range of temperature studied was 0.011 per cent per degree Centigrade. The volume change during solidification varied from an expansion of 1.65 per cent in a gray (hypereutectic) iron to a contraction of 5.85 per cent in a low-carbon low-silicon type of iron." (The "gray" iron contained 3.63 per cent carbon and 2.87 per cent silicon, while the "low-carbon, low-silicon type" of iron contained 2.29 per cent carbon, 1.24 per cent silicon.)

Fundamentals of Freezing of Gray Iron

It probably will be well at this time to give some consideration to the alloy diagram most nearly representative of the composition of gray cast iron in general, and the fundamentals of the freezing of a gray iron. Figure 2 is a reproduction of the iron-carbon-silicon equilibrium diagram taken from *"The Alloys of Iron and Silicon,"* by Greiner, Marsh and Stoughton[2]. It can be seen that hypoeutectic irons possess an increasing range of temperature over which freezing takes place as the carbon content is reduced. The closer the carbon content is to the eutectic composition, the shorter will be the freezing range. The lower carbon irons, having the longer freezing ranges, hence the greater volume changes (contraction) during solidification, are more susceptible to shrink holes and porosity and, therefore, require more care in gating and feeding. With a short freezing range and a lower volume change, the irons of nearly eutectic composition are least subject to shrinkage and porosity difficulties. Since the graphite and austenite of a given weight occupy a greater volume than the same weight of cementite, or austenite alone, it can readily be understood that the higher carbon irons, which will contain more graphite, will have a greater volume after solidification than a low carbon gray iron or a white iron and will, therefore, possess a decreased tendency toward the formation of shrinkage cavities.

The presence of other elements, such as sulphur, phosphorus, manganese and the usual alloying elements, tend to alter this diagram considerably but, due to the complexity of studying more than three variables, we lack sufficient quantitative data to indicate the effects of these additional elements upon the iron-carbon-silicon system. However, we do know that an iron containing 0.41 per cent phosphorus is not completely frozen until a temperature of approximately 1750° F. is attained, and it is logical to assume that additions of other elements also may influence the eutectic temperature.

[1]Saeger, C. M., Jr., and Ash, E. J., *"Volume Changes of Cast Irons During Casting,"* TRANSACTIONS, American Foundrymen's Association, Vol. 40, pp. 172-187, (1932).

[2]Greiner, E. S., Marsh, J. S., and Stoughton, B., *"The Alloys of Iron and Silicon,"* p. 140, (1933), Alloys of Iron Monograph Series, Engineering Foundation, published by McGraw-Hill Book Co., New York, N. Y.

In 1937, Boyles[3] presented a paper which added considerably to our fundamental knowledge. To this work, I am indebted for the following summarization of the solidification of a hypoeutectic gray cast iron:

> "When the metal reaches the liquidus, the first crystals to form are the primary austenite dendrites which continue to grow until the metal attains the eutectic temperature. They are entirely independent of any other feature in the final structure. Since they are formed first, all that transpires later is confined to the spaces between them. They are never completed due to the intervention of a new mechanism, the freezing of the eutectic, hence they remain simply the skeletons of crystals. When the melt reaches the eutectic temperature, solidification begins at various centers which grow equally in all directions, forming masses of spherical shape. Graphite flakes are formed immediately upon freezing and continue to grow radially as the spheres develop in size. The result is a rosette of graphite flakes centered about each crystallization point."

The following two quotations are also taken from the paper:

(1) "Graphite flakes do not begin to form until the eutectic begins to freeze."
(2) "As soon as the eutectic is completely frozen, the flake structure is essentially complete."

How Iron Solidifies

With these fundamentals in mind, we can more readily visualize what would happen to a pool of molten iron trapped within a solid mass. When the liquidus temperature is reached, the dendrites of austenite start to precipitate from the mother liquor and a slight contraction in volume takes place. These dendrites become intermingled and build up a lattice work within the liquid. As they continue to form, the contraction in volume accompanying the change of state from liquid to solid, lowers the level of the liquid iron, exposing the dendrites at the top of the original pool, and the unfilled spaces between them form the voids which make up the undesirable porosity, sponginess, or shrink. When the eutectic starts to freeze, there may be further reduction in volume or there may be a slight increase in volume, depending upon the composition. The size of the original pool, the temperature gradient between solid metal and liquid metal, the quantity of graphite formed upon solidification of the eutectic, the rate of cooling, and perhaps the surface tension of the liquid, determine the size of the voids and the extent of the porous section.

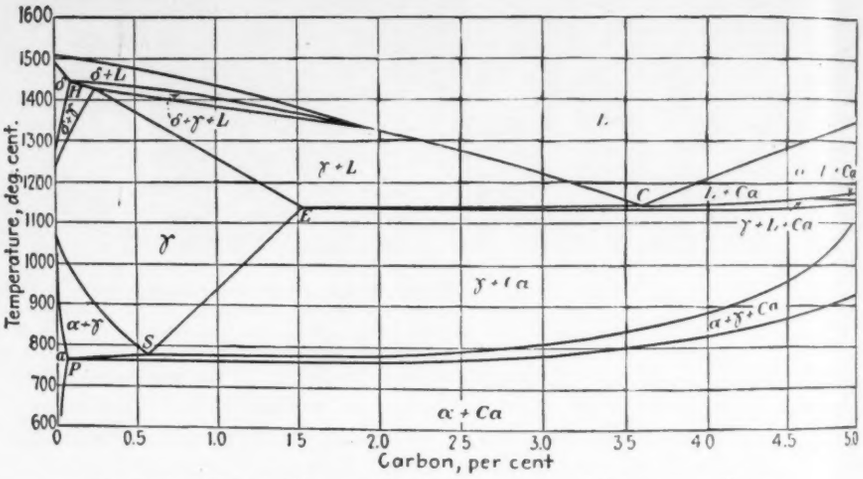


Fig. 2—Iron-Carbon-Silicon equilibrium diagram at 2.0 per cent silicon.

It thus is conceivable that with a fine network of austenite dendrites, a high melting point for the eutectic, a relatively high surface tension for the liquid and a small pool of trapped liquid, that the actual volume of voids would be so finely divided as to be almost obscure. However, with a large volume of trapped metal, a low melting point for the eutectic, a low surface tension and a slow rate of cooling, resulting in the formation of larger dendrites with greater spaces between them and a greater opportunity for the liquid to filter down through these dendrites as solidification proceeded, there would be an increased tendency to form large voids or shrink holes.

Temperature Gradients

Temperature gradients always exist in a casting. The metal adjacent to the walls of the mold is cooled quickly and solidification takes place within a short time, producing a shell of solidified metal, which grows in thickness as the heat from the molten interior is dissipated through this shell to the sand of the mold. Solidification takes place in a direction perpendicular to these walls. If the casting consists of a thin section whose longest dimension is in a vertical position, it is highly probable that some of the section will contain shrinkage cavities midway between the two vertical sides, because there will not be sufficient metal to completely fill the mold after solidification has been completed and there are no forces present to push the sides together to take up the contraction in volume. If the thin section were cast with its longest dimension in the horizontal position, the force of gravity would tend to pull the top surface downward, constantly maintaining a pressure which would aid in reducing, or perhaps eliminating, the formation of voids. Again, as soon as the top surface pulls away from the sand mold, there is formed an air gap which would reduce the conduction of heat away from the casting at that surface and cause most of the freezing to proceed from the bottom surface upward.

For a given composition, the greater the temperature gradient between the outside and the inside of an improperly fed casting, the greater will be the void volume remaining after solidification has been completed. These gradients may be increased by mold de-

[3]Boyles, A., *"The Freezing of Cast Iron,"* Iron and Steel Division, TRANSACTIONS, American Institute of Mining and Metallurgical Engineers, Vol. 125, (1937), pp. 141-203.

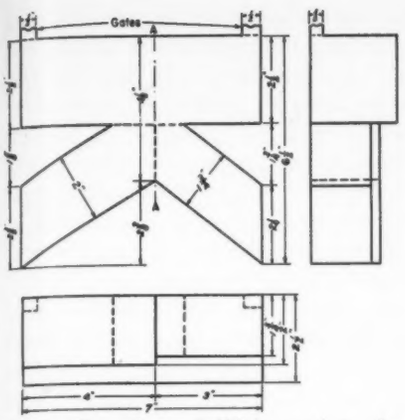


Fig. 3—Dimensions of K-bar, used to determine shrinkage propensities of gray iron.

signs which place heavy sections next to light sections by increasing the size of the section itself, by increasing the moisture content of the mold, by the insertion of chills, and by raising the pouring temperature.

Methods of Controlling Porosity

In attempting to control porosity in a production foundry, it is a general practice to establish some simple cast specimen which is used as a criterion for the performance of an iron with regard to shrinkage in a special type of casting which is being produced. For example, let us consider the production of engine blocks, units which often present serious difficulties in the production of sound castings. One large production foundry uses a wedge shaped casting poured in an open mold with the thin edge downward. It has been found that this particular wedge shows an internal shrinkage cavity in the heavy section when shrinkage defects also occur in certain parts of the motor block. Another foundry has established its criterion in a K-bar, dimensions of which are shown in Fig. 3. The K-bar is gated at the bottom of the heavy section and the casting lies horizontally in the mold. After solidification, this casting is nicked with a saw cut at the junction of the three sections and fractured with a hammer blow. Figure 4 shows two irons which produced shrinkage cavities when poured into this casting, and one iron which produced a sound casting.

Another production foundry found that the solidification of a 4-in. cube most nearly duplicated the casting conditions existing at a critical location on one of their motor blocks. In determining the shrinkage characteristics of a new iron, the 4-in. cube was cast and sawed in half after solidification was complete. If the saw cut revealed a shrinkage cavity at the center of the cube, they could expect to find defects at the critical location in the motor block. When the cube was sound, motor blocks poured with the same composition and pouring temperature also were found to be sound.

Figures 5 and 6 show the method of gating this casting and the types of cavities produced by different compositions.

These castings, not being fed by risers or heads, actually measure what might be termed the "self-feeding" tendencies of an iron and can be used to study such variables as composition and pouring temperature. Having been requested to cooperate with the foundry using the 4-in. cube on a production problem, our laboratory had the opportunity to conduct several experiments using this type of test specimen.

Molds used for the production of these castings were made of baked sand. The bottom consisted of a slab 2-in. thick. The sides of the mold were 4-in. thick, and the cope consisted of a 1-in. thick slab. Directly above the casting the cope was provided with a ½-in. diameter hole to allow for the escape of displaced air. The mold was completely filled for each test, allowing some of the metal to spill out through the vent. The usual practice was to allow the casting to cool to room temperature, then cut the sample in half on the vertical plane of symmetry which bisected two of the sides. This saw cut usually exposed the shrinkage cavity whenever one was formed. However, saw cuts made along the other vertical plane of symmetry, perpendicular to the first, showed that one saw cut was not always sufficient to reveal the true nature of the shrinkage cavity and it was doubtful if any number of cuts could readily reveal the characteristics of the porous section. For this reason, the laboratory decided to attack the problem along more quantitative lines.

Measurement of Void Volume

It was apparent, from a few experiments, that the more logical approach to the problem would be a measurement by density determinations of the void volume, which comprised the shrinkage cavity. Accordingly, a high capacity precision balance, built upon the principle of a flexure plate and having a sensitivity of one part in 1,000,000 with a load of 16-lb. on each arm, was constructed. After the castings had solidified and cooled to room temperature, they were carefully ground to remove the sand. They were then weighed on the balance in air and in water to determine their weights and volumes. After these measurements had been determined,

Fig. 4—Fractures of K-bars. Note that the one on the right shows no shrinkage.

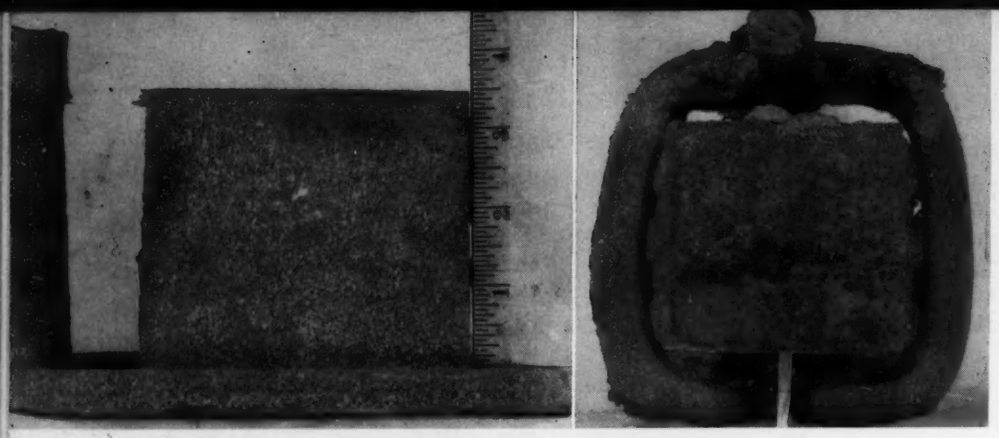


Fig. 5A (left)—Method of gating 4-inch cube casting. Side view. Fig. 5B (right)—Same as Fig. 7, but top view.

each cube was sectioned through the center and a 10-in. cube taken from one of the lower corners was prepared and surface ground on all sides. The density of this 1-in. cube was accurately determined on a precision balance in the chemical laboratory by the Archimedes principle.

Assuming that the density of this corner cube represented the density of sound iron throughout the block, the total weight of the 4-in. cube in air was divided by the density of this corner cube to find the actual volume of iron in the larger cube. This value was subtracted from the volume of the larger cube and the remainder was taken as the void volume of the shrinkage cavity. Using this method, experiments were run to determine the effects of changes in composition and pouring temperature. One experiment also was conducted to determine the effect of removing the cope side of the mold upon the position of the shrinkage cavity. Below are outlined some of the results which were obtained in these experiments.

Results of Control Experiments

The series of experiments was conducted using a base composition of the following analysis:

	Per Cent
Carbon	3.25
Manganese	0.60
Silicon	2.25
Sulphur	0.12
Phosphorus	0.12
Chromium	0.30
Copper	0.12
Molybdenum	0.70
Nickel	0.16

In every case, the heat was made up from a synthetic charge superheated to 2800° F. and cooled to 2600° F. before it was poured. Except for one variable in each case, the heats were charged and run according to one schedule, identical throughout.

1. In the range 0.01 to 0.74 per cent, phosphorus was found to increase the void volume as follows:

Phosphorus, Per Cent	
0.015	0.35 cc.
0.036	0.43 cc.
0.073	2.12 cc.
0.104	2.62 cc.
0.123	2.96 cc.
0.74	12.75 cc.

2. In the range 0.52 to 1.32 per cent, manganese showed a decrease in void volumes as it increased from 0.52 to approximately 1.00 per cent, after which an increase in this element resulted in an increase in shrinkage of comparatively small order of magnitude.
3. Deoxidizers, such as ferrosilicon, aluminum and zirconium, tended to increase porosity.
4. With this particular composition, varying the carbon content from 3.01 to 3.44 per cent and silicon from 1.39 to 2.85 per cent did not materially affect the void volume, nor did increasing the sulphur content from 0.04 to 0.15 per cent.
5. Increasing the pouring temperature from 2400 to 2850° F. produced a pronounced increase in void volume:

2400° F.	1.9 cc.
2550° F.	2.65 cc.
2700° F.	3.4 cc.
2850° F.	4.5 cc.

While this 4-in. cube casting may effectively duplicate the conditions found in a certain location of a large motor block, it must be recognized that the actual conditions of solidification are not identical. The test casting would probably be a better criterion for the behavior of different compositions when cast in heavy sections, where the temperature gradient from the mold wall to the interior of the casting is large. In this large casting, beside the contraction of the iron due to the volume change from the pouring temperature to the solidus, there is also the contraction of the outer solidified shell due to normal thermal contraction as the metal cools. This condition often takes place while the interior is still in the liquid condition. In some cases, the rate of contraction of the solidified shell is enough faster than the rate of solidification that the interior is actually subjected to a high pressure and the weakest part of the wall, usually at the top of the casting, bursts, forcing some of the metal at the interior to be exuded at the surface, forming beads or "peas." This phenomenon is often referred to as liquation. Several of the blocks shown in Fig. 6 exhibited this condition.

However, it will be noted that, although this phenomenon had taken place, the interiors of some of the blocks contained shrinkage cavities, indicating that there came a time when the pressure was reduced and the solidification took place under conditions conducive to the formation of voids. It may be that the reduction in pressure was the result of the allotropic change of the iron from the gamma phase to the alpha phase, a transition accompanied by the expansion of the metal. In other words, the center of the cube may have solidified after the outside shell had transformed to pearlite.

Solidification of Cube

Our observers of the solidification of the inadequately fed 4-in. cube indicated that the first iron to become solid was the metal next to the sand walls of the mold, as would be expected. However, as soon as part of the metal next to the mold solidified, there was enough contraction to cause the top surface to recede from the cope slab and thereafter the top of the casting cooled more slowly than the four

sides and the bottom. Depending upon such factors as the strength of the iron at elevated temperatures, the differences in the rates of solidification between the metal at the top and that adjacent to the mold at the other faces of the cube, and perhaps the degree of undercooling, the top of the casting would sink varying amounts as solidification progressed. In some cases, there would be a slight concavity of the entire top surface; other times there would be deep craters formed which would only affect part of the top surface. These conditions have been illustrated in Fig. 6. In our experiments, there was apparently no correlation betweeen the sink at the top of the casting and the void volume of the casting or even the composition poured. In the covered mold, the shrinkage defect at the interior of the casting was always above the horizontal plane of symmetry and nearly equi-distant from the four sides.

When the cope slab was removed from one of the molds, the top of the casting, now exposed to the air, cooled more rapidly than the bottom. There was very little sink at the top surface and the shrinkage cavity was forced to a position below the horizontal plane of symmetry. This experiment showed clearly the effects of cooling rates and temperature gradients upon the formation of the shrinkage cavity.

A Second Approach

Because the calculated void volume for some of the cubes cast for these experiments indicated appreciable cavities, yet saw cuts through the cubes failed to reveal cavities which could be seen by the naked eye, a more comprehensive test was conducted on four more cubes. After casting, and allowing the cubes to cool to room temperature, they were cleaned and their weights and volumes were determined. Each cube was then sectioned to produce a slab 1-in. thick, 4-in. high and 4-in. long, consisting of one side of the cube. The density of this slab was determined and the value obtained was used to determine the void volume of the 4-in. cube. This was compared with the void volume computed when the 1-in. cube, taken from a lower corner, was used as a representative of the sound iron. The two values obtained for each 4-in. cube are tabulated below:

	Void Volume in c.c.			
	2475	2462	2464	2466
a) by 1x4x4-in. cube....	.19	.21	.67	2.25
b) by 1x1x1-in. cube..	.98	1.46	1.63	2.9

Eleven other 1-in. cubes, representative of each position in the larger casting, were prepared and their densities determined. These experiments indicated that the density of the iron varied for different positions in the casting, and, in most cases, the densities of the other cubes were less than the density for the corner cube. Part of the value which was formerly regarded as void volume, therefore, could be attributed to a reduction in density in other positions in the cube.

The 1x4x4-in. slab was more representative of the sound metal in the cube, and the value for void volume determined by using the density of this slab, as the density of sound iron, produced more accurate results. However, for the four cubes in question, both methods placed them in the same order. In the two cases where the shrinkage cavity was sufficiently large to be visible to the naked eye, the cube whose edge corresponded to the vertical line of symmetry of the 4-in. cube, and whose base lay in the horizontal plane of symmetry, possessed the lowest density. This was expected, since this cube contained part of the shrinkage cavity.

However, in two of the cubes which did not exhibit visible porous sections, this same cube showed a density nearly equal to the density of the bottom corner cube. In one case the corner cube was actually less dense than the interior cube referred to. No

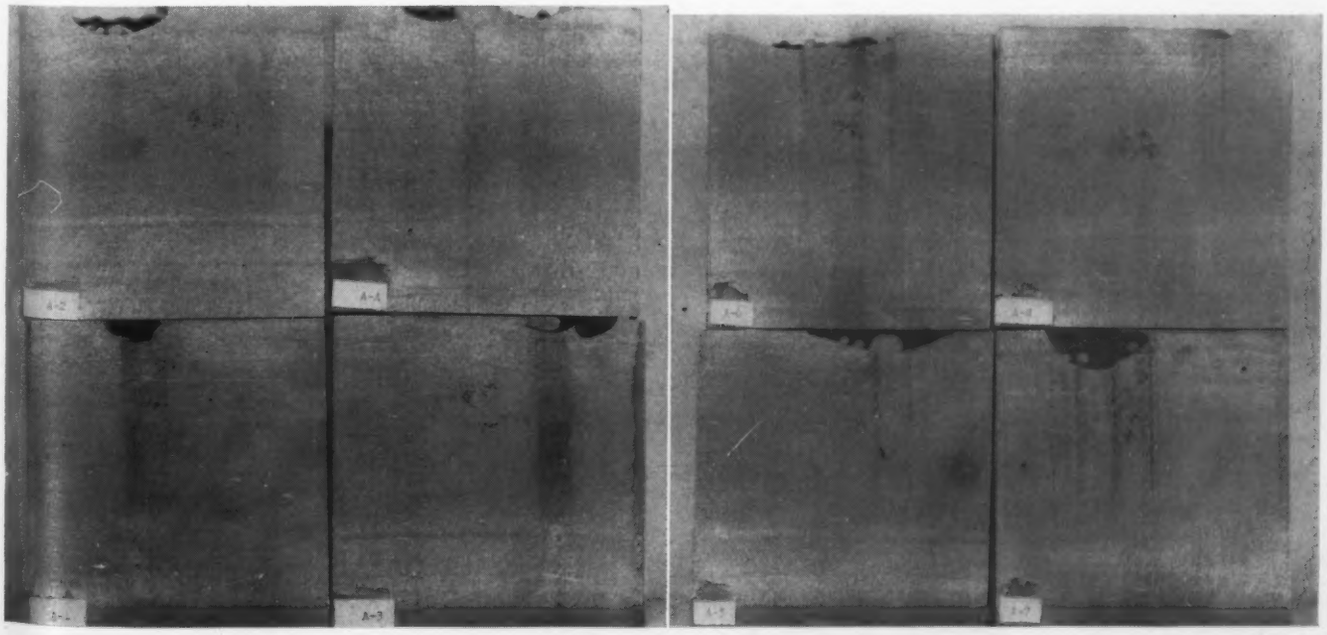


Fig. 6—Shrinkage defects in 4-inch cube casting. Note cavities where metal has exuded to the surface. This phenomenon often is termed liquation.

attempt has been made to explain this phenomenon, but it seems as if pressure existing during the time of solidification may have some effect upon the density of the iron.

Other variables, such as proper placement of castings in the mold, gating, placement of risers, correct mixtures of molding sands and adjustment of moisture content, will be mentioned here only with regard to their effects on temperature gradients.

Methods of Reducing Shrinkage

After the mold has been correctly built, the foundryman is faced with the production of a sound casting possessing specified hardness and tensile properties with perhaps a desired microstructure. To achieve the desired specifications, he may adjust his carbon-silicon ratio and make certain alloy additions. Considering the theoretical aspects of shrinkage, the following variations may be made to reduce the tendency toward shrinkage in certain locations of the casting which possess the least perfect feeding conditions:

1. *Reduction in elements which tend to increase the freezing range,* particularly those that substantially lower the eutectic temperature. While phosphorus always has had the reputation of increasing the castability of an iron, it does so by materially reducing the eutectic temperature, thereby permitting the iron to remain fluid a longer time at a given cooling rate. However, it is this effect which makes a high phosphorus iron more subject to shrinkage defects, particularly in large castings with heavy sections. For this reason, it is recommended that the phosphorus content always be held as low as possible in heavy pressure castings.
2. *Reduction in pouring temperature.* By reducing the pouring temperature as much as possible, temperature gradients may be reduced within the casting and freezing may proceed more uniformly, since the interior of the section will not have so much heat to dissipate before solidification begins.
3. *Gating through light sections and risers.* Gating through light sections, and sometimes even risers, aids materially in reducing steep temperature gradients and permits the riser to be a source of liquid metal for a longer time due to the heating of the sand of the mold by flowing a large volume of metal past it. These methods are dealt with by Scott[4].
4. *Proper control of pouring rates.* The rate at which a casting is poured tends to influence temperature gradients. It is necessary to compromise on this factor to pour the casting as slow as possible to reduce the temperature gradients, and perhaps provide liquid metal to fill vacancies already formed by solidification shrinkage, and yet fast enough to prevent mis-runs.
5. *Use of Chills.* Chills may be used in certain locations of molds to hasten solidification in certain sections so that they may be fed by molten metal from adjacent sections which may be in more favored positions to be fed by risers or still heavier sections.

This discussion concerned with the theory of shrinkage has by no means exhausted all of the possible angles of approach. It is hoped that it has served as a provocation for more information on this important problem of cast iron founding.

[4]Scott, M. A., *"Production of Uniform Dense Structures in High Test Alloy Iron Castings,"* TRANSACTIONS, American Foundrymen's Association, Vol. 47, pp. 513-533 (1939).

Committee of Cupola Research Project Has 3-Point Program

THE Cupola Research Project of the Association, organized to direct a coordinated study of the theory and practice of melting iron in the cupola, now has its program under way. Inception of the project was brought about through a realization of the need for a better and clearer understanding of the fundamental principles governing cupola melting, and because of the further realization that cupolas were being operated on a basis of somewhat generally accepted tradition, which in many cases has been borne out by facts.

The committee has laid out a 3-point program: (1) To review the published literature; (2) to coordinate known data and publish this information in a handbook on cupola operation; and (3) to conduct research work so as to develop authoritative information on practices and theories at present unproved.

Cupola Experts Serve

The general cupola research project, as organized, has for its membership some 80 of the best-known cupola experts and technicians in the country. General direction of the project is under control of a Steering Committee headed by D. J. Reese, foundry research engineer, International Nickel Co., New York. Mr. Reese now is serving with the metallurgical and specification units of the Iron and Steel Section, Materials Divisions, War Production Board, Washington, D. C. Other members of the Steering Committee are:

D. J. Reese

Max Kuniansky, works manager, Lynchburg Foundry Co., Lynchburg, Va.

S. C. Massari, Captain, U. S. Army Ordnance, Chicago, and

Max Kuniansky

S. C. Massari

formerly Director of Research, Association of Manufacturers of Chilled Car Wheels.

R. G. McElwee, foundry engineer, Vanadium Corp. of America, Detroit, and Forgings and Castings Unit, Products Section, War Production Board, Washington, D. C.

John L. Lowe, foundry engineer, Battelle Memorial Institute, Columbus, Ohio.

More Contributors

The committee project, while sponsored by the A.F.A., is being financed through special contributions of the foundry industry. Raising of funds for the work is conducted by a committee headed by Max Kuniansky. A list of contributors to the cupola project was published in the July issue of *American Foundryman*, and other contributions have since been received, as follows:

Cupola Research Project

Additional 1941-42 Pledges, as of July 7, 1942

T. L. Arzt Foundry Co., Chicago, Ill.
Atlas Foundry Co., Detroit, Mich.
Baker Perkins Co., Inc., Saginaw, Michigan.
Bassett Foundry Co., Adrian, Mich.
Central Iron Foundry Co., Detroit, Michigan.
Certified Core Oil & Mfg. Co., Chicago, Ill.
Chevrolet Grey Iron Foundry, Saginaw, Mich.
Continental Roll & Steel Foundry Co., East Chicago, Ind.
Crane Co., Chicago, Ill.
Detroit Edison Company, Detroit, Michigan.
Detroit Steel Casting Co., Detroit, Michigan.
Enterprise Engine & Foundry Co., San Francisco, Calif.
Ford Motor Co., Dearborn, Mich.
Gale Mfg. Co., Albion, Mich.
Great Lakes Foundry Sand Co., Detroit, Mich.
The Hydro-Blast Corp., Chicago, Ill.
Hyman-Michaels Co., Chicago, Ill.
Inland Lime & Stone Co., Manistique, Michigan.
International Harvester Co., Chicago, Illinois.
M. S. Kaplan Co., Chicago, Ill.
Little Bros. Foundry Co., Port Huron, Mich.

R. G. McElwee

John L. Lowe

Michigan Alkali Co., Detroit, Mich.
Michigan Malleable Iron Co., Detroit, Mich.
Michigan Steel Castings Co., Detroit, Michigan.
Miller & Co., Chicago, Ill.
C. H. Milles Foundry Co., Chicago, Illinois.
Motor & Machinery Castings Co., Detroit, Mich.
Nichol-Straight Foundry Co., Chicago, Ill.
Packard Motor Car Co., Detroit, Michigan.
Peerless Pattern Works, Detroit, Michigan.
Riley Stoker Corp., Detroit, Mich.
United States Graphite Co., Saginaw, Michigan.
A. T. Wagner Co., Detroit, Mich.

Ordnance Flag to Belle City Malleable for High Production

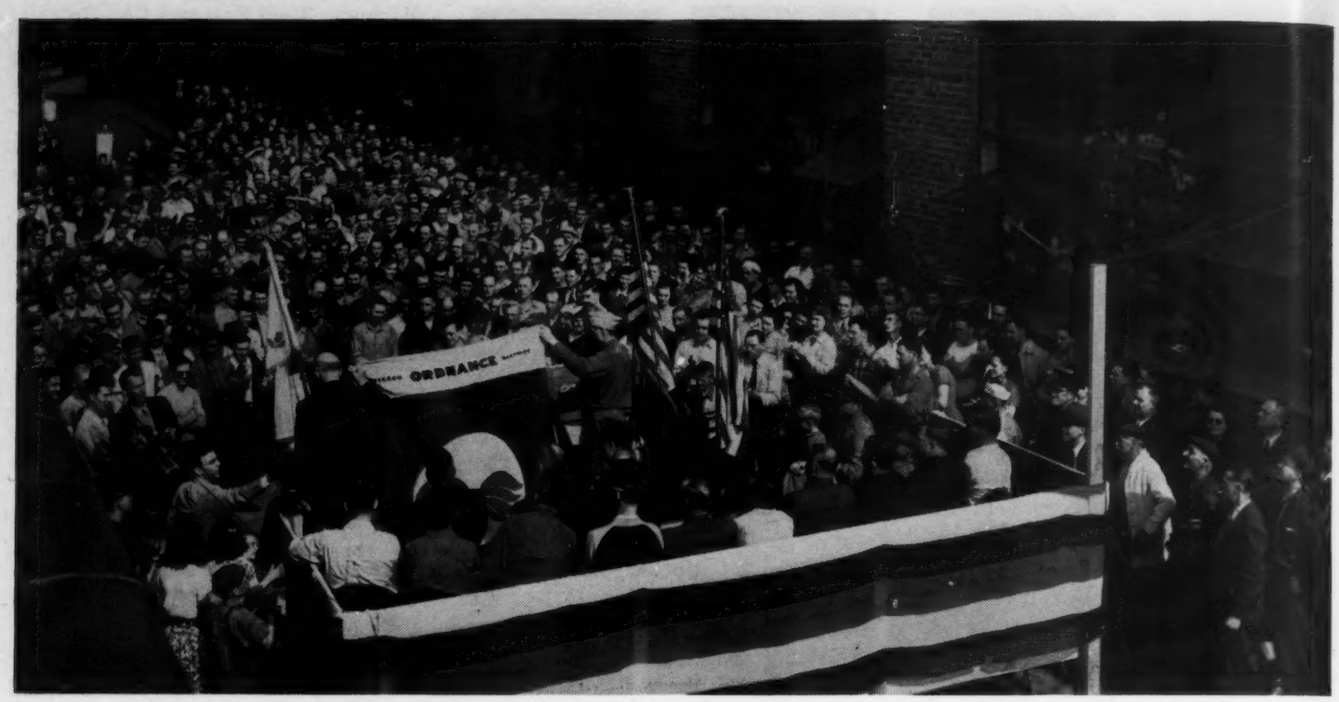
FOR its cooperation with the Chicago Army Ordnance district in doubling production of vital war materials in a period of 18 months, the Belle City Malleable Iron and Racine Steel Castings companies received the Army Ordnance flag at appropriate ceremonies held at the plant June 3. C. S. Anderson, president of the company, received the flag, which was presented by Lt. Col. Wm. B. Hobbs of the Chicago ordnance office.

The Belle City firm was one of the first in Racine to convert to 100 per cent war production. Management, shop committees and employees were praised for their part in accomplishing its increased schedules, and Mr. Anderson pledged his company to a continued increase in production of war products.

Earlier this year the Belle City company celebrated its fiftieth year in the foundry business, with a banquet for members of the firm's "25 Year Club," consisting of employees having 25 or more years of continuous service. President of the club is Frank Hady, who has served over 50 years, starting with the company in 1892 when it was founded. Forty-four officers and employees of Belle City have been with the company for at least a quarter century, aggregating 1,563 years of service, or an average of 35 years for each man.

Among the members of the

C. S. Anderson (right), president, Belle City Malleable Iron Co., Racine, Wis., receives for his company from Lt. Col. Wm. B. Hobbs, the Army Ordnance flag for the Chicago Ordnance district, for outstanding service in production of war materials.



Emblem of meritorious war production, the Army Ordnance flag was presented June 3 to the Belle City Malleable Iron and Racine Steel Castings companies for doubling production of vital war materials in 18 months. Employees received a major share of the credit at the presentation ceremonies held outside the Racine, Wis., plant.

club are Judson F. Stone, chairman of the board, with 35 years service; C. S. Anderson, 28 years; and Stanley Kitto, treasurer, 25 years. In commemoration of its "golden anniversary," the company has issued an interesting booklet entitled "Fifty Years," in which the production of malleable castings and steel castings are well illustrated.

Aid Offered Foundries In Apprenticeship Work

ONE of the most timely addresses presented at the recent A.F.A. convention in Cleveland was that of Wm. F. Patterson, Chief of Apprenticeship, U. S. Department of Labor, Washington, D. C. As a result, the A.F.A. has now been asked to cooperate with the government in working out planned apprenticeship programs within the foundry industry.

A few years ago the present vital demand for all-around mechanics was foreseen. As a result, the Federal Committee on Apprenticeship was formed to work out recommendations for a general apprenticeship program, and to put it into effect. Subsequently this work was brought under the Department of Labor and field representatives were appointed to contact employers and employees. On July 1st the work was transferred to the Federal Security Agency under the title of "Apprentice-Training Service."

Through A.F.A., the government now is asking that foundry management and labor sit down with these representatives and work out planned apprenticeship programs in the industry. Where there exists a bargaining agreement with a recognized union, Joint Committees are formed with management and labor having equal representation. Otherwise, the programs are developed exclusively with management.

Work of Field Men

The field representatives were required to pass Civil Service examinations based on practical knowledge of apprentice training. They have already established approximately 1,500 planned programs covering 185,000 indentured apprentices. They may be useful in establishing Advancing Worker Programs; in cooperating with such governmental agencies as the Training-Within-Industry branch of the W.P.B., and in connection with Selective Service deferment of apprentices in war production plants having one of the planned programs.

Field representatives of the Apprentice-Training Service are available in many cities for consultation on training problems. Foundry executives desiring to contact nearest field representatives should communicate with R. E. Kennedy, Secretary of A.F.A., 222 W. Adams St., Chicago, Ill.

Aluminum-Magnesium Alloy Dust Real Hazard

HAZARDS connected with the production of magnesium metal are now well known wherever lightweight metals are being used for the manufacture of aircraft parts. It does not seem to be so well known, however, that the dust of aluminum-magnesium alloys can be equally hazardous, if proper precautions are not taken. A recent foundry accident reported in "California Safety News" makes the point an important one.

In this case a workman was grinding castings consisting of a 50-50 alloy of aluminum and magnesium, intended for airplane parts. The grinder was partially enclosed with a hood, and the

dust was carried by air flow to a receiver nearby, about 2 ft. in diameter and 2½ ft. high. Somehow the dust in the receiver ignited and the resulting fire, almost explosive in nature, caused the death of the workman standing right beside the receiver.

While aluminum is not usually considered flammable, in powdered form it can become so under certain conditions, especially when added to magnesium. The point is worth emphasizing that either aluminum or magnesium or any mixture of them, in a finely divided state, should be handled with great care and every possible precaution taken to prevent ignition.

A.S.T.M. President Lundell Pays Tribute to Early Work of A.F.A.

G. E. F. LUNDELL, Chief of the Chemistry Division, National Bureau of Standards, Washington, D. C., in presenting his address as president of the American Society for Testing Materials before their annual meeting held June 24 at Atlantic City, N. J., gave a masterly dissertation on "Chemical Requirements and Chemical Analysis." At the same time he paid high tribute to Dr. Moldenke and other men of the A.F.A. for the cooperation they displayed during the early part of the present century.

Early Standards Work

In discussing the history of the standard sample work of the Bureau, Mr. Lundell cited the suggestion made in 1889 by John W. Langley before the Engineers' Society of Western Pennsylvania, at which time Mr. Langley declared:

"A practical remedy for most of these differences of analytical reports can be found in a system of international standards of iron or steel, whose composition shall be most rigidly and authoritatively determined by committees of chemists and metallurgists, appointed in the most important iron-producing countries. These committees propose to analyze a set of samples which shall be prepared in one place and distributed to the several countries; after the committees have made their reports, the standards thus established will probably be deposited in some public place, and small portions of them can then be issued to properly qualified applicants.

"A chemist obtaining a sample of the standards can then check his own work by them, and thus he can determine a factor by which in future his results must be multiplied to make them agree with the standards. It is confidently believed that the plan, if successfully carried out, will result in a very considerable degree of uniformity in the analysis of these important metals in different countries and will greatly lessen those scientific and commercial disputes which now sometimes assume formidable proportions."

A.F.A. Contribution

President Lundell continued this quotation with the following remarks: "The elusive factors by which analysts' results must be multiplied to make them agree with the standards were never determined, for after five samples were prepared and considerable work was done, the project fell through and the samples were never distributed as planned.

"In the meantime, the American Foundrymen's Association prepared and distributed standardized pig iron samples, comprising four sets and covering a considerable range of compositions. In 1905 these samples were turned over to the National Bureau of Standards. The announcement by Dr. Moldenke, then secretary of the American Foundrymen's Association, and for a number of years the chairman of our Committee A-3 on Cast Iron, is interesting:

" 'We beg to announce the taking over by the Government of our Standardizing Bureau, and that hereafter the Standardized Drillings of Cast Iron prepared and sold by our Association are to be obtained from the Bureau of Standards of the Department of Commerce and Labor. The American Foundrymen's Association has been highly honored by this recognition of its work, and the undoubted broadening out of the preparation of standard drillings now to be expected will greatly enhance the value of standards for check determinations in the iron and steel industry.' "

Start of Sample Work

Dr. Lundell further stated that in the same year that the A.F.A. had turned over to the Bureau their standardized pig iron samples, the American Chemical Society assigned to the Bureau their samples of argillaceous limestone and zinc ore. From this start the Bureau's work has grown to cover 130 samples.

A.F.A. *Transactions*, vol. 12 (1903), contains a report of this early work, written by Thomas D. West as chairman of the Committee of the Standardizing Bureau and referring to three years of work. The work, Mr. West stated, was financed by special subscriptions amounting to $1700. This example of coordinated effort, made possible through the facilities of the Association, has been followed in a number of other notable cases, for example, the Sand Research Project, and the Cupola Research Project.

Neal B. Hamilton (right), apprentice in the 4-year foundry course of Caterpillar Tractor Co., Peoria, Ill., receives a certificate and cash award as the Gray Iron molding winner in the 1942 national A.F.A. Apprentice Contest. M. J. Gregory, factory manager of Caterpillar's foundry division, and an A.F.A. director, presents the awards. Hamilton's winning casting can be seen in the foreground.

A United Industry

WHEN our forefathers founded this Nation and later drew up its Constitution, they were faced with the problem of finding a name or title for this new babe among the nations. Anyone who has read American history is familiar with the divergence of opinion which existed among the leaders and people of the Thirteen Colonies, the difficulties of the first Congresses, etc. Yet, our forefathers were united in one purpose. They wanted freedom and were willing to sacrifice and die for it.

Of all the designations which probably were proposed for the new Nation, it is significant that they chose *"United* States of America." Not "America" nor "American States" but *United* States of America. There has seldom, if ever, been united thought among the peoples of this country on any particular subject but there have been many, many times when there has been a unity of purpose.

It is the same unity of purpose evidenced by the people of the United States in the time of a national emergency or national peril, and their determination to fight for those things they hold dear, which must have been one of the motives that led those nations fighting for their very existence and mode of life against the Axis powers to term themselves the United Nations.

If nations, representing large groups of people, can unite for their common good, why cannot relatively small groups do so? It is a recognized fact that the larger the group on which effort is expended to secure unity, the more difficult is the realization of the goal. The foundry industry certainly involves less individuals than the nation. Accordingly, it should be easier to unify the castings industry than nations. Why has it been difficult in the past to secure unity in the castings industry? The answer is competition.

Normally, competition within the castings industry is a war of materials. Steel castings attempt to replace malleable, gray iron to replace steel, non-ferrous castings to replace gray iron, and so on. Such a situation leads to close holding of information because of the advantage which it gives a company over its competitor. Under such circumstances, the advancement of the castings industry as a whole is difficult because the exchange of information is limited and it is only through the exchange of information that the quality of product can be improved. It is not the good castings which influence the wider usage of the casting process, it is the poor ones. Good castings are accepted as expected. The failure of one casting, be it gray iron, steel, malleable or non-ferrous, reflects discredit on the entire industry.

The present war has focused attention on the usefulness of castings of all types. Never has the industry in general been pushed to produce so much. Never have the difficulties in securing the desired production and quality been greater. Yet, never has the opportunity been greater to establish castings, irrespective of type or metal, as a quality engineering material. Here is the opportunity to dispel in the minds of manufacturers and design engineers the suspicion of castings as voiced in an essay by a student of a leading engineering educational institution, "Many manufacturers and design engineers are prejudiced and distrust the reliability of anything cast."

This war has changed the competitive situation entirely. Industry as a whole has only one customer, Uncle Sam. We are told that this is a steel war. Steel foundries are pressed to capacities never dreamed of before, many times with little or no additional equipment. The non-ferrous castings industry, particularly the aluminum and magnesium branches, are expanding at rates unvisualized several years ago. The malleable and gray iron foundries are producing well but apparently the total available capacities of these branches of the casting industry are not overtaxed.

In addition to being a war of production or a steel war, as some people speak of it, this is a war of materials and between materials. Not only must the victor produce war goods of the proper quantity but of the proper type. The side which holds control of the largest supply of materials and can outproduce the opposition not only in quantity but in quality and effectiveness will win. We *must* be the winners.

Already we are feeling the pinch of the materials situation. While some branches of the industry are being increased in capacity through the building of new plants and through the conversion of foundries of one type to another, it seems necessary that substitution of other types of castings be made to relieve that foundry capacity which is necessary for the production of those types of castings most essential to a successful prosecution of the war. This means that many foundries will be called upon to produce castings of a type with which they are totally unfamiliar. Such foundries will have many headaches with the possibility of undermining all the work that has been done in the past by all organizations interested in castings to establish in the minds of engineers the fact that castings are quality engineering materials. Those who produce castings from a type of metal with which they are familiar have many problems also, but foundries entering a new field of production will have infinitely more.

For these reasons, it is essential that there be a free exchange of production information not only between foundries of a given branch of the industry but between all foundries, irrespective of type or class of product produced. Only through such a wide exchange of information can the quality level of castings be maintained and increased. Such an exchange of information is mandatory if the industry is to contribute its maximum to the war effort and to maintain a high reputation for a quality product gathered during this national emergency.

Let us adopt throughout the industry an attitude of helping the other fellow. Such an attitude will establish the industry on a high quality basis and will help your country win the war.

We must win or there will be no Uncle Sam!

The Place of Light Non-Ferrous Castings in Aircraft Production

This article gives information on the various types of aluminum and magnesium alloys used to cast various parts for aircraft. The first section of the paper is devoted to a discussion of the various processes used to cast aluminum and magnesium alloys. The consideration regarding the adaptability of the process to the particular design is discussed. Information is given on the minimum section thickness which can be produced by each of these processes, the usual finish allowance required, application, compositions, physical properties, commercial equivalents, heat treatment, and corrosion improvement methods.

NON-FERROUS castings are playing a prominent part in the manufacture of aircraft units and aircraft accessories in the war effort. The greatly increased production, forced on the foundries by our enormous military program, is overtaxing their capacity. The foundries are expanding as fast as possible, and many are changing over from a jobbing type foundry, where only a few castings are made from each pattern, to a continuous in-line production foundry where many thousands of castings are made from each pattern.

In the past, before the beginning of World War II, the aircraft industry for military planes was highly competitive and very much in the experimental stage. Few planes of one type were manufactured at a time. The designs were changing rapidly, and neither planes, engines nor accessories were manufactured appreciably ahead of actual orders. Now, however, our national defense and Victory programs demand standardization of design and conversion of aircraft and accessory plants from jobbing to inline continuous production. To maintain the pace of the aircraft industry's growth and to meet its requirements for a continuous flow of castings, the foundries also have had to expand rapidly and change over to continuous production.

The Victory program demands standardization, not only in design but also in material. Specifications for type alloys were and are being standardized for more ready interchangeability. A great effort is being made to decrease the number of different casting alloys used. The critical shortage of certain strategic metals is helping this endeavor to eliminate special alloys and to standardize tonnage alloys.

Alloy Series

Non-ferrous casting alloys for the aircraft industry may be classified into four types, namely, aluminum, magnesium, copper, and zinc alloys. The order of consumption and demand is as indicated. The greatest demand is for aluminum and magnesium alloys, due to their low densities. The least demand is for zinc casting alloys, although the use of zinc is rapidly increasing as a substitute for aluminum and magnesium wherever the higher density of the zinc alloys is not of major importance. Copper castings are used to a limited extent, owing to the high density of copper alloys, although the strength and corrosion resistance of copper alloys are very much desired.

Types of Castings

The casting alloys may be classed in four groups as follows:

1. Sand.
2. Permanent and Semi-Permanent Mold.
3. Die.
4. Plaster Mold.

All but the die casting group of alloys may be further sub-divided into non-heat-treatable and heat- treatable alloys. In the former group, the improvement in properties is accomplished by alloying alone; in the latter, heat treatment processes are used to enhance further the mechanical properties.

Adaptability

The type of casting process which is used will depend upon several factors. For large and for intricately cored castings, the use of sand molds is necessary. Because a metal mold or steel die is required, the use of die and permanent mold castings can be considered only where a sufficiently large number of castings of the same pattern will be be used to justify the cost of the mold or die.

The die casting process is particularly adapted to the quantity production of relatively small castings in which close dimensional tolerances are required and the cost of finishing must be held to a minimum. The dimensional tolerances of permanent mold castings are intermediate between those of sand castings and those of die castings, and the surface finish approaches that of die castings. Plaster mold castings are similar to sand castings but with smoother surfaces and closer tolerances.

Permanent Molds

Many of the sand cast alloys can be cast successfully in permanent molds, but in other cases special alloys have been developed for this purpose. Permanent mold castings have the advantage over sand castings in greater ultimate strength but lower ductility, more exact size and better surface.

Permanent mold castings are used where a superior product is required, or when a forging cannot be used, either because of the form of the part or because of cost considerations. The strength of a casting produced from a given alloy in a permanent mold is about 10 per cent greater than that obtained from a sand casting. The dimensions may be controlled more accurately than in a sand mold casting, and either a machined or polished surface generally will show greater freedom from porosity. In addition to superior mechanical properties, they also have

greater resistance to corrosion and greater susceptibility to heat treatment, due to the fine grain and greater density of the metal.

Die Casting

The die casting process is adapted to the production of castings in which extreme accuracy, uniformity and superior finish are essential. In this process, very thin walls may be cast with a consequent saving of weight in the finished product. Holes may be cast to very close tolerances and the dimensions can be controlled so closely that they reduce machining operations to a minimum. Die cost is high so that this process is suitable only for castings which are produced in large quantities.

The great advantage of the die casting process is that it makes possible rapid production of castings which are substantially exact duplicates of each other. Pressure and chilling action in die casting result in fine grain castings. However, due to the rapid chilling, much air can be entrapped with subsequent porosity. All die castings, are, therefore, subject to internal porosity and consequently do not possess high impact strength and ductility. The new high-pressure die casting methods produce sounder and denser die castings.

Plaster Molds

Plaster mold castings are obtained from molds made by pouring a liquid mixture of gypsum (calcium sulphate), water and suitable binder, such as asbestos, into a flask containing the metal pattern. The molds are allowed to set and harden, then are removed from the flask and baked to completely calcine and dry, leaving them very porous to allow gases to escape. The cores are made in the same fashion as the molds. The castings produced by this process have surfaces almost as smooth as metal mold castings.

Section Thicknesses

Sand casting alloys may be cast in the smaller castings with $\frac{1}{8}$-in. minimum wall thickness. The usual allowance for machining is 1/16-inch. Permanent mold castings, depending on size and design, can be cast with 3/32-in. minimum wall thickness. The overall dimensions can usually be held to $\pm$ 0.010-inch. Usually, 1/32-inch is allowed for machining. Sections in die castings can be produced as thin as 0.020-inch, although 1/16-inch is preferred. A section tolerance of $\pm$ 0.0025-inch can be held. Plaster mold castings can be held to tolerances of $\pm$ 0.005-inch and better.

Aircraft production has vastly increased demand for non-ferrous castings.

Casting Alloys

By the addition of various alloying elements or "hardeners" to aluminum and magnesium, not only tensile strength but casting properties also are improved. By alloying alone, strengths almost double that of commercially pure aluminum and magnesium are obtained. The elements commonly used as hardeners for aluminum are copper, silicon, magnesium, zinc, manganese, nickel and iron. The elements commonly used as hardeners for magnesium are aluminum, manganese and zinc.

ALUMINUM ALLOYS

Aluminum-Silicon. Aluminum-silicon alloys are very fluid, have excellent casting characteristics, and thus are used for thin-walled and complicated castings. The castings are very dense and leak-proof. They have a lower specific gravity than other aluminum alloys and good corrosion resistance. They are alloys of low tensile strength and low yield strength. High aluminum-silicon alloys are difficult to machine.

Aluminum-Copper. Aluminum-copper alloys respond to heat treatment and, therefore, have high strength and hardness. These alloys are not used for very thin sections and the castings are not as pressure-tight as castings of the aluminum-silicon alloys. They possess a desirable combination of good casting characteristics, together with good machinability.

Aluminum - Copper - Silicon. Copper and silicon, when added together to aluminum, make the alloys particularly suitable for permanent mold and sand casting applications because of their excellent casting characteristics. They can be used for large and intricate sand castings. These ternary alloys have a wide application, since they respond well to heat treatment, producing excellent mechanical properties. They are leak-proof, pressure tight and retain their strength up to 400°F. This group of alloys attempts to combine the casting characteristics of the aluminum-silicon alloys with the mechanical properties and machining characteristics of the aluminum-copper alloys.

Aluminum-Magnesium. Aluminum-magnesium alloys are difficult to cast, but they have maximum resistance to corrosion.

These alloys have lower specific gravity and excellent mechanical properties. They are not recommended for intricate or leak-proof castings.

Aluminum - Magnesium - Copper. These alloys are excellent heat-treatable alloys; magnesium added to the binary aluminum-copper alloys increases the response of these alloys to heat treatment.

Aluminum-Nickel-Magnesium. Nickel with magnesium in aluminum alloys is very effective in maintaining the high properties at elevated temperatures, and in providing an alloy not subject to permanent growth on heating. These alloys retain strength up to 600°F. They respond well to heat treatment and become very hard after complete ageing following the solution treatment. Care must be exercised in casting these alloys.

Properties of Aluminum Aircraft Alloys

Tables 1, 2 and 3 show the typical compositions, typical physical properties and commercial equivalents of aluminum aircraft alloys.

MAGNESIUM ALLOYS

Aluminum added to magnesium refines the grain, increases yield strength, increases hardness and decreases ductility. Zinc added to magnesium increases corrosion resistance and strength after heat treatment. Manganese added to magnesium increases its resistance to salt water corrosion.

Characteristics Classified

Magnesium casting alloys may be classified according to their characteristic uses, as shown in Table 4.

Physical Properties

Table 5 shows typical physical properties of the alloys given in Table 4. Designation for the heat treatments are explained in the footnote in Table 5.

General Foundry Practice

Sand casting of aluminum and magnesium alloys is the method most frequently resorted to in obtaining castings for aircraft construction. Wood patterns are frequently used, but metal patterns are desirable where there is quantity production. There is practically no limit to the size or core complexity of castings made by this method. Such foundry considerations as section thickness, gating, risering, chilling, pouring temperature, permeability and moisture content of the sand, and any other factors which influence the rate of metal solidification, have a material effect on the mechanical properties of the castings.

Cast aluminum and magnesium alloys have low strength at temperatures just after solidifying and, if free contraction of the metal is not permitted, cracks may be produced in the castings. Therefore, the sand molds must be relatively soft and cores must soften at low temperatures in order to obtain sound castings. The low specific gravity of the aluminum and magnesium alloys makes extra venting necessary so that all gases can be removed rapidly from the molds.

In sand castings, 3/16-in. per foot is allowed for unrestrained shrinkage, and 5/32-in. per foot is allowed for restrained shrinkage by bosses or cores. In die castings, the maximum permissible wall thickness is 0.375-in., while the minimum permissible wall thickness is 0.060 inch.

Design Precautions

Magnesium cast alloys in heat-treated form exhibit excellent tensile properties and fatigue resistance but are sensitive to conditions producing local stress concentrations. They are satisfactory for applications demanding high fatigue strength if care is taken to avoid sharp corners

Table No. 1

Composition, Physical Properties and Commercial Equivalents of Aluminum Sand Casting Alloys

Composition (Typical)

Alloy Designation	Copper, per cent	Silicon, per cent	Iron, per cent	Magnesium, per cent	Nickel, per cent	Aluminum, per cent
43	.....	5	.....	.....	.....	Remainder
47	.....	12.5	.....	.....	.....	Remainder
122	10	.....	1.2	0.2	.....	Remainder
142	4	.....	.....	1.5	2	Remainder
195	4	.....	.....	.....	.....	Remainder
214	.....	.....	.....	3.8	.....	Remainder
220	.....	.....	.....	10	.....	Remainder
355	1.3	5	.....	0.5	.....	Remainder
356	.....	7	.....	0.3	.....	Remainder

Properties (Typical) (See Note Below)

Alloy Designation	Tensile Strength, p.s.i.	Yield Strength, p.s.i.	Elongation, per cent	Compressive Yield, p.s.i.	Sheer Strength, p.s.i.	Fatigue Strength, p.s.i.	Brinell Hardness
43	19000	9000	6.0	10000	14000	6500	40
47	26000	11000	8.0	11000	18000	6000	50
122-T2	25000	20000	1.0	20000	21000	9500	75
122-T61	36000	30000	1.0	43000	29000	.....	100
142-T2	27000	18000	1.0	18000	21000	6500	75
142-T61	37000	32000	0.5	47000	32000	8000	100
195-T4	31000	16000	8.5	16000	24000	6000	65
195-T6	36000	22000	5.0	25000	30000	6500	80
214	25000	12000	9.0	12000	20000	5500	50
220-T4	45000	25000	14.0	26000	33000	7000	75
355-T4	30000	20000	4.0	25000	30000	.....	60
355-T6	35000	25000	3.5	29000	30000	8500	80
356-T4	28000	16000	6.0	18000	22000	.....	55
356-T6	32000	22000	4.0	22000	27000	8000	70

Commercial Equivalents

Alloy No.	S.A.E.	Army	Navy	Federal	Aircraft Materials Specifications
43	35	11311	46 Ale Class 2	QQ-A-601 Class 2	
47	37				
122	34		M-212a Class 6	QQ-A-601 Class 7	
142	39	57-71-1cA	M-212a Class 5	QQ-A-601 Class 6	
195	38	57-72- 5B	46 Ale Class 4	QQ-A-601 Class 4	
214	320	57-72- 4A	46 Ale Class 5	QQ-A-601 Class 5	
220	324	11309-A	M-186c		
355	322	11307-A	M-212a Class 10	QQ-A-601 Class 10	4210-A
356	323	11308-A	46 Ale Class 3	QQ-A-601 Class 3	4212-A, 4214

Note: Data taken from materials suppliers records. Heat treatment designations: T2=Annealing Treatment; T4=Solution Treatment; T6=Solution Treatment plus Ageing; and T61=Solution Treatment plus Ageing.

and abrupt changes in section. Portions of a casting that are highly stressed should be provided with liberal fillets blended into the body of the casting. The edges of cored holes and webs should be beaded. Stud bosses should be of ample size with good radii provided at their bases. When magnesium alloy castings replace aluminum, increases in wall sections are seldom required. When they replace cast iron or steel, a redesign of the important sections is necessary.

Uses and Applications

ALUMINUM ALLOYS

Sand Castings. Alloy 43 (Tables 1, 2, 3) has low tensile and low yield strength. Owing to its high fluidity, it is used for complicated and thin walled castings. It is dense, leak-proof, and has good corrosion resistance. It is used for carburetors, hot air scoops, fuel line fittings, fuel and oil tank flanges, oil pans, gear case covers and accessory housings. This same alloy is used for castings of the types indicated when cast by the permanent mold and die casting processes.

Alloy 47 (Table 1) is an alloy of higher silicon content than alloy 43 with subsequent higher strength when modified. It is the lightest and most fluid of all the aluminum alloys, but is more difficult to machine and tap. Its uses are the same as for alloy 43, but for thinner walled and more complicated castings and also for castings requiring higher mechanical properties.

Alloy 122 (Table 1) is a heat-treatable alloy used for parts subject to high temperature and requiring high hardness and strength. It is used for pistons, carburetors, intake manifolds, bearing surfaces and air-cooled cylinder heads.

Alloy 142 (Table 1) is a heat-treatable alloy known also as "Y" alloy. It maintains its strength well at elevated temperatures up to 600°F. It is used for cylinders, air-cooled cylinder heads, pistons and bearing surfaces.

Alloy 195 (Table 1) is one of the most commonly used heat-treatable alloys, having good strength and high shock resistance. It is not as corrosion resistant as the aluminum-silicon alloys, but machines better and has greater strength. It is used for most structural castings, gear cases, crankcases, gear housings, oil pans, controls, rudder pedals, sockets, horns, some cylinder heads, propeller gear boxes, superchargers, transmission gear cases and covers for dirigibles, and also starter and generator housings.

Alloy 214 (Table 1) does not respond to heat treatment. It is more difficult to cast than the aluminum-copper and aluminum-silicon alloys and is not recommended for intricate or leak-proof castings. It has excellent corrosion resistance, high ductility, and strength intermediate between alloy 43 and the heat-treated alloys. It is used for housings and parts of simple design requiring high corrosion resistance.

Alloy 220 (Table 1) is a heat-treatable alloy of excellent resistance to corrosion, especially to high octane aviation gasoline. It is not recommended for leak-proof castings, castings of thin-walled sections, or for castings for use at elevated temperatures. The alloy is more difficult to cast than the other aluminum-base alloys, requiring special sand and handling practice.

Alloy 355 (Table 1) is one of the best aluminum casting alloys, as it has excellent casting qualities and retains its strength well at elevated temperatures up to 400°F. It is leak-proof and pressure tight. It also responds well to heat treatment. It is used for liquid-cooled cylinder heads, cylinder blocks in liquid-cooled engines, propeller gear boxes, gear housings, superchargers, crankcases, accessory housings, etc. It is also used for cylinder heads in air-cooled engines of intermediate horsepower.

Alloy 356 (Table 1) is used as a substitute for alloy 195 when the casting is very complicated. Ageing alone will improve the properties, but quenching and ageing will produce the maximum properties. It is used for cylinder heads and cylinder block in liquid-cooled engines. It is also used for many of the applications referred to under alloy 195.

Permanent Mold Castings. Alloy 43 has the same characteristics and applications, where cast in permanent molds, as when cast in sand molds.

Alloy A108 (Table 2) combines the desirable characteristics of both the aluminum-silicon and the aluminum-copper alloys.

Alloy 122 (Table 2) is used for brake shoes, bearing caps, pistons, camshaft bearings, where high hardness and good bearing properties are required.

Alloy A132 (Table 2) has lowest coefficient of expansion and lowest weight of the permanent mold aluminum alloys. It possesses excellent bearing and wearing qualities and is used for brake shoes, bearing caps and engine pistons.

Alloy 142 (Table 2) is used for pistons, brake shoes, air-cooled cylinder heads.

Alloy B-195 (Table 2) is used for pistons, bearing caps, and wherever alloy 195 sand castings are used.

Alloy 355 (Table 2) is one of the best alloys, as it has excellent casting qualities and retains

The quality of non-ferrous castings for aircraft must be of the highest.

Table No. 2

Composition, Properties and Commercial Equivalents of Permanent Mold Aluminum Casting Alloys

Composition (Typical)

Alloy Designation	Copper, per cent	Silicon, per cent	Iron, per cent	Magnesium, per cent	Nickel, per cent	Aluminum, per cent
43	.....	5	.....	.....	.....	Remainder
A108	4.5	5.5	.....	.....	.....	Remainder
122	10	.....	1.2	0.2	.....	Remainder
A132	0.8	12	0.8	1	2.5	Remainder
142	4	.....	.....	1.5	2	Remainder
B195	4.5	2.8	.....	.....	.....	Remainder
355	1.2	5	.....	0.5	.....	Remainder

Properties (Typical) (See Note Below)

Alloy Designation	Tensile Strength, lb. per sq. in.	Elongation, per cent	Brinell Hardness
43	21,000	2.5	40
A108	24,000	0.5	70
122-T52	30,000	0.0	105
122-T65	40,000	0.0	140
A132-T4	34,000	1.0	100
A132-T551	31,000	0.0	105
142-T61	40,000	0.0	110
142-T571	34,000	0.0	105
B195-T4	33,000	4.5	75
B195-T6	35,000	2.0	90
355-T6	37,000	1.5	95

Commercial Equivalents

Alloy Designation	S.A.E.	Army	Navy	Federal
43	35	.....	46-A-15 Class 7	QQ-A-596 Class 7
A108	.....	.....	46-A-15 Class 5	QQ-A-596 Class 5
122	34	.....	46-A-15 Class 2	QQ-A-596 Class 2
A132	321	.....	46-A-15	QQ-A-596
142	39	.....	46-A-15	QQ-A-596
B195	.....	.....	46-A-15	QQ-A-596
355	322	.....	46-A-15	QQ-A-596

Note: Data taken from publications of materials producer.

its strength well at elevated temperatures up to 400°F. It is leak-proof and pressure tight. It also responds well to heat treatment. It is used for propeller gear boxes, gear housings, superchargers, crankcases, accessory housings, etc.

Die Castings. Alloy 13 (Table 3) has good casting qualities, highest fluidity and freedom from hot shortness. It has relatively high strength and good corrosion resistance. It is used for housings, instrument and accessory parts, bomb-rack anchors, air intake check valves and large intricate castings.

Information given in preceding paragraph dealing with the use of alloy 43 in sand castings also is applicable to die castings made from that alloy.

Alloy 85 (Table 3) has good casting qualities and gives a good combination of strength and ductility. It is used for housings, instruments and accessory parts, cockpit enclosure parts, de-icing manifolds, brackets and parts of heavy sections.

Alloy 218 (Table 3) has excellent resistance to corrosion and excellent strength and ductility. It does not cast as well in intricate castings as alloy 13. It is used for fittings and castings requiring high strength and resistance to corrosion, airplane wheel flanges, and brake shoes.

MAGNESIUM ALLOYS

The magnesium alloys shown in Tables 4 and 5 have the following applications in aircraft construction:

Permanent Mold Castings. Landing wheels, crankcases, starter and generator housings.

Die Castings. Engine rocker box covers, shroud tube fittings, accessory housings.

Sand Castings. Engine crankcases, gear cases and covers, engine nose sections, tail wheel assembly parts, brake assemblies, starter housings, pump housings, intake manifolds, oil sumps, supercharger rollers, hydraulic pump bodies, thrust bearing housings, diffuser plates, camshaft housings, generator housings, window frames, pedals, wheels, tail forks, de-icer pumps, blower sections, engine rear sections, automatic pilots, distributors, instrument cases and parts, control column parts, rear and front supercharger sections.

General Information on Alloys

To expedite aircraft production and facilitate the manufacture of light metal castings, a concentrated effort is being made to reduce to a minimum the number of alloys used. This has a marked beneficial effect on all concerned in the refining, casting, heat treating and fabricating of light metals. Fewer alloys mean less chance for contamination in the foundry and offer

Table No. 3

Composition, Properties and Commercial Equivalents of Aluminum Die Casting Alloys

Composition (Typical)

Alloy Designation	Copper, per cent	Silicon, per cent	Magnesium, per cent	Aluminum, per cent
13	....	12	....	Remainder
43	....	5	....	Remainder
85	4	5	....	Remainder
218	....	....	8	Remainder

Properties (Typical)

Alloy Designation	Tensile Strength, lb. per sq. in.	Yield Strength, lb. per sq. in.	Elongation, per cent	Brinell Hardness	Charpy Impact, ft. lb.	Endurance Limit, lb. per sq. in.
13	33,000	18,000	1.8	80	2.0	15,000
43	29,000	13,000	3.5	65	4.5	.....
85	35,000	19,000	2.7	70	2.5	17,000
218	36,000	23,000	5.0	....	10.0	17,000

Commercial Equivalents

Alloy Designation	S.A.E.	Army	Navy	Federal
13	305	57-93-1B Gr. 2	46 A-14 Cl. 1 and 2	QQ-A-591 Cl. 1 and 2
43	304	57-93-1B	46 A-14 Cl. 3 and 8	QQ-A-591 Cl. 3 and 8
85	307	57-93-1B Gr. 1	46 A-14 Cl. 5	QQ-A-591 Cl. 5
218	.....	.....	46 A-14 Cl. 7	QQ-A-591 Cl. 7

more castings of the same alloy that can be heat treated at the same time.

Since a high, strength-weight ratio is a prime factor in aircraft design, the mechanical properties of the alloys are given first consideration, machinability and corrosion resistance being secondary in most cases.

The popular aluminum alloys are the equivalents of alloys 142, 195 and 355 for sand castings; alloys 142, B195 and 355 for permanent mold castings; and alloy 13 for die castings. The popular magnesium alloys are the equivalents of alloys H and C for sand castings, alloy H for permanent mold casting and alloy R for die castings.

Table No. 4

Classification of Magnesium Alloys According to Characteristics

Heat-Treatable Alloys

Alloy Designation	Casting Process	Composition, per cent (Typical) Alum.	Mang.	Zinc	Silicon	Magnesium	Characteristics
G AM-240	Sand and Permanent Mold	10.0	0.10	....	....	Remainder	Moderate tensile strength and leak-proofness
AM-241	Sand and Permanent Mold	8.0	0.10	....	....	Remainder	High impact strength and high ductility
B AM-246	Sand	12.0	0.10	....	....	Remainder	High hardness, high yield strength and low elongation
C AM-260	Sand	9.0	0.10	....	....	Remainder	Soundness and leak-proofness and requiring high strength. Pressure tight castings
H AM-265	Sand and Permanent Mold	6.0	0.20	3.0	....	Remainder	High physical properties and fine grain

Non-Heat-Treatable Alloys

M AM-403	Sand		1.2-2.0	....	0.3 Max.	Remainder	Good stability and welding characteristics
K AM-230	Die	10.0	0.10	0.5	....	Remainder	Thin walled die castings of moderate strength
R AM-263	Die	9.0	0.20	0.6	....	Remainder	Good strength die castings (general)

Heat Treatment

ALUMINUM CASTINGS

Certain aluminum castings, through the addition of alloying elements, will respond to heat treatment which imparts mechanical properties superior to the alloys in the "as-cast" condition. Various heat treatments may be used, depending upon the size of castings and the physical properties desired.

As a general rule, the heat treatment consists of two processes: namely, the solution treatment, which is carried out in the range of 900 to 1000°F., and an accelerated age or precipitation heat treatment at from 300 to 600°F. The solution treatment is usually done in electric furnaces, since it has been found that slight traces of sulphur in the furnace atmosphere will materially affect the castings, because of intergranular embrittlement which results. Circulatory fans are placed in the furnaces to provide a uniform distribution of the heated air.

The solution treatment, which takes from 6 to 14 hours, is usually followed by rapid quench in boiling water. Because of the strain induced upon the castings as a result of the quench, intricately designed castings are likely to crack. In such cases, the quench must be eliminated, with the resultant lowering of mechanical properties.

In a period of 3 to 4 months after solution treatment, castings will undergo an ageing reaction, resulting in an increase in tensile strength, yield strength and hardness, with a decrease in ductility. This precipitation hardening proceeds rapidly at first, and, for all practical purposes has sufficiently progressed after 3 or 4 days to give expected solution treated properties.

Complete ageing may be accelerated by a precipitation heat treatment. This may be done in either an electric or gas-fired oven and consists of an intermediate age or over-age. The latter treatment is given castings where complete stability and maximum tensile strength are desired.

In cases where stability of the material is desired and where maximum physical properties are not necessary, a simple precipitation treatment may be employed, which consists of about a 450°F. age for a period of 6 to 8 hours.

MAGNESIUM CASTINGS

Certain magnesium alloys also respond to similar heat treatments. For solution treatment, the castings are heated in a cir-

Table No. 5

Typical Physical Properties of Magnesium Alloys

Alloy Designation—	AM-240 and G, H.T.*	AM-240 and G, H.T.A.**	AM-241, H.T.	AM-246 and B, H.T.A.	Am-260 and C, H.T.	Am-260 and C, H.T.A.
Tensile Strength, lb. per sq. in.	33000	34000	33000	32000	38000	38000
Yield Strength, lb. per sq. in.	12000	19000	11000	20000	14000	20000
Elongation, per cent	8	1.0	10.0	0.5	10	3.0
Shear Strength, lb. per sq. in.	20000	22000	18000	19000	20000	22000
Charpy Impact, ft. lb.	.....	0.7	2.2	0.5	.....	0.8
Brinell	52	69	48	85	61	78
Endurance Limit, lb. per sq. in.	10000	8000	7500	7000	10000	10000

Alloy Designation—	AM-265 and H, H.T.	AM-265 and H, H.T.A.	AM-230 and K, As-Cast	AM-263 and R, As-Cast	AM-403 and M, As-Cast
Tensile Strength, lb. per sq. in.	37000	37000	30000	33000	14000
Yield Strength, lb. per sq. in.	12000	18000	22000	20000	4000
Elongation, per cent	10.0	4.0	1.0	3.0	5.0
Shear Strength, lb per sq. in.	18000	19000	.....	.....	11000
Charpy Impact, ft. lb.	2.5	1.1	.....	.....	.....
Brinell	53	69	68	66	33
Endurance Limit, lb. per sq. in.	10000	9000	.....	.....	.....

Commercial Equivalents

Alloy	A.M.	A.M.S.	Navy	Army	S.A.E.
C	.....	4434	M112 Alloy 17	.....	500
G	240				
H	265	4420A, 4422A, 4424A	M112 Alloy 4	57-74-1C	50
K	230		M369	11319	.....
M	403		M112 Alloy 11	.....	.....
R	263	4490	M369	11319	501

* Solution Heat-treated.
** Solution Heat-treated and Aged.

culating-type furnace to a temperature of 730 to 760°F. for a period of about 20 hours. Unlike aluminum, however, it is not necessary to quench the castings after solution treatment. The properties are obtained by a quick air cool. The ageing or precipitation heat treatment takes place at 350°F. for 16 to 20 hours.

At the solution treatment temperature, especially in the case of alloy C, which requires the highest temperature, there is a danger of scorching of the castings. Therefore, it is advisable to introduce atmospheric control; usually an atmosphere of sulphur dioxide. Since traces of sulphur are detrimental to the heat treatment of aluminum castings, they should never be heat treated in a furnace containing sulphur fumes from a previous magnesium heat.

Corrosion Protection

ALUMINUM CASTINGS

Several chemical treatments have been developed for improving the appearance and corrosion resistance of aluminum castings. The most widely used for aircraft parts is an electrochemical method for forming an aluminum oxide film, known as anodizing or Alumiliting.* Castings to be treated by this process are first thoroughly cleaned and then suspended from the anode into an electrolyte composed of 5 to 10 per cent chromic acid or 15 to 18 per cent sulphuric acid. The latter electrolyte is the Alumilite process and, because of the porous condition of the oxide film, provides a method of dyeing the casting to produce any desired surface color. These processes will make aluminum resistant to better than 700 hours exposure in a 20 per cent salt spray solution. Dimensional changes from the above treatments are about 0.0001 or 0.0002-in. and do not, therefore, materially affect threaded or other close tolerance surfaces.

A chemical treatment, known as the Alrok* treatment, has been developed where a less resistant coating can be used and where a less expensive process is desired. Electrical generating equipment is not necessary and production costs are lower. This process is used extensively as a paint base, since the surface coatings are not as thick or as abrasive resistant as the electro-chemical coatings.

*Patented process.

MAGNESIUM CASTINGS

An anodic treatment for magnesium castings has been developed and is known as the PT13 treatment, which is the Navy Aeronautical Specification for the process. The castings, after cleaning, are anodized in an electrolyte of dilute sodium dichromate and monosodium phosphate by passing an electric current through for about 30 minutes. The most commonly used magnesium alloys should withstand approximately 200 hours salt spray when given this treatment.

Chemical treatments of magnesium, which have been developed by two suppliers of magnesium metal, are more widely used than the electrochemical anodic treatment.

Rough castings and wrought stock generally are given a chrome pickle treatment, which consists of a short-time dip in a solution of sodium dichromate and citric acid. The treatment passivates and slightly etches the surface of the metal, which gives, as a result, a surface well adapted for painting. Because of the etching effect of the solution, about 0.001-in. of metal will be removed, making this process impractical on finish machined parts. It does, however, have the advantage of very low dielectric properties, which are necessary in one-wire electrical systems.

Finish machined castings usually are given an alkaline dichromate treatment, consisting of a dip in dilute hydrofluoric acid, followed by boiling in sodium dichromate. An improved modification of this process involves boiling the castings after the hydrofluoric acid dip in a solution of ammonium sulfate, sodium dichromate and ammonia, and sealing this coating in a dilute solution of boiling arsenous oxide. When the dichromate treatments are used, a high dielectric film is formed which must be removed if electrical conductivity between assembled parts is desired.

Impregnation

There are often applications of magnesium or aluminum castings where pressure tightness is necessary, and frequently castings which are otherwise satisfactory are subject to rejection because of seepage when pressure tested.

Several methods have been developed for impregnating porous castings, wherever this method of salvage is acceptable. Solutions of sodium silicate, lacquer or bakelite are generally used for aluminum castings, and chinawood oil or lacquer for magnesium castings.

The process consists of a prebake to drive the moisture from the castings, after which they are placed in a pressure chamber which is evacuated. The impregnated solution is then allowed to flow into the chamber, covering the castings, after which pressure is applied to force the solution into the evacuated pores. The castings then are removed from the pressure chamber and baked to harden or polymerize the solution as the case may be. After baking, the castings are sandblasted and pressure tested. Castings showing visible blow holes or other large defects are never given this treatment.

References

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4. Allen, A. H., *The Foundry*, August 1939.
5. Grant, L., *Metal Industry*, December 1939.
6. Woldman, N. E., *Metals and Alloys*, October 1940.
7. Woldman, N. E., *Iron Age*, February 27, 1941.
8. Woldman, N. E., *Iron Age*, March 6, 1941.
9. Ward, R. E., *The Foundry*, May 1941.
10. Aluminum Co. of America, Publications and catalogues.
11. Dow Chemical Company, Publications and catalogues.

Did you know that practically all insulating refractories are sized on cutting tables after they have been fired?

Questionnaire now being used in the Chicago Metropolitan area in conjunction with their plant protection code based almost entirely on the A.F.A. Code. (See article, p. 27.)

OFFICE OF CHIEF OF INDUSTRY, OFFICE OF CIVILIAN DEFENSE, CHICAGO METROPOLITAN AREA

PLANT PROTECTION INSPECTION REPORT

Name of Plant.....No. of Employees.....
Address.....
Party Interviewed.....Title.....Phone No.....
Has a copy of Code been received?.....Serial No.....Is copy wanted?.....
Is the plant doing any war work?.....Working how many shifts?.....How many days?.....
POLICE: Has plant personnel been investigated?.....Fingerprinted?.....
Are employees required to wear identification badges?.....
Are plant visitors checked and identified?.....Given badges?.....
Has a plant defense coordinator been appointed?.....For each shift?.....
Is there a plant police department?.....Number.....Armed?.....Deputized?.....
What distinguishes police from other employees?.....
Are day patrols maintained?.....Night patrols?.....
Are all gates and entrances guarded?.....Number of entrances.....
Are trucks, vehicles, freight cars and boats inspected on arrival?.....
FIRE: Construction: Fireproof.....Mill.....Ordinary.....Floor Area.....
Height, stories.....
Is adjacent property a fire hazard?.....
Is there a plant fire department?.....How many full-time firemen?.....
Number of volunteer firemen.....Frequency of drills.....
Is size of fire department adequate for all emergencies?.....
Are premises sprinkled?.....Are sprinkler valves open and sealed?.....
Are all sprinkler and fire system valves plainly marked?.....
Are there sufficient hose connections?.....Number.....Size of hose.....
What sources of auxiliary water for fire-fighting?.....
Types of portable extinguishers:.....Are they sealed?.....
Are they in working order?.....Frequency of inspection.....
Are there sand boxes and shovels on roofs?.....Barrels of water?.....
Other means for fighting incendiary bombs.....
Are there gas masks for any toxic gases and fumes to be encountered?.....
Does good housekeeping prevail?.....
How often are fire inspections made by plant organization?.....
Are police and firemen instructed in the fire problem?.....
Have fire watcher stations been located on highest roofs?.....Number.....
Have fire watchers been appointed?.....
YOUR GENERAL REMARKS ON FIRE PROTECTION:.....
.....
MEDICAL: Is there a plant medical department?.....No. of doctors.....No. of nurses.....
Number trained in Red Cross First Aid.....Is there a dispensary?.....
Number of stretchers.....Are they properly located around plant?.....
ENGINEERING: Is there a plant engineering chief?.....For each shift?.....
Are all maintenance men under his supervision?.....
Have emergency tools and equipment been provided?.....
Are all substations, power houses and boiler houses under lock and key?.....
Are fences necessary around plant?.....Is plant fenced?.....
Are gas, water and electric utility entrance valves and switches to plant properly identified?.....
Are they protected against tampering?.....
BLACKOUT: Are there operations that produce fire and glare visible outside?.....
Have means been provided for blacking out the fire and glare in an emergency?.....
Has the plant practiced a blackout?.....
Has the plant worked out details for a blackout if official orders are given?.....
Can city fire equipment get through plant roadways?.....
If plant has not started any protection program when will it do so?.....
When should the plant be interviewed again?.....
What is your general impression of their plant protection efforts?.....
.....
.....

INSPECTOR.....DATE.....194....

Australian Foundrymen Form Own Association

THE first annual volume of the Proceedings of the new Institute of Australian Foundrymen, covering the years 1939-40, was recently received by A.F.A. and contains interesting data on formation of the society, as well as a number of papers on foundry practice presented at the first annual meeting, April 17, 1940.

A number of interesting papers were presented before the 1940 annual meeting, dealing with electric furnace melting, steel and non-ferrous foundry practice, sand testing, production and uses of pig iron and coke, cupola practice, and iron foundry developments.

Copies of the first annual proceedings of the Institute of Australian Foundrymen may be obtained from A.F.A. at a cost of $3.00.

A.F.A. Plant Protection Code Getting Widespread Recognition

WHEN the A.F.A. Safety and Hygiene Codes Committee, under the able and tireless leadership of Jas. R. Allan, International Harvester Co., Chicago, prepared the Wartime Plant Protection Code, it had one purpose in mind. That was to provide the foundry industry with a simple, practical and inexpensive method for safeguarding vital castings production, and the properties and employees necessary for turning them out. The splendid code that was formulated, quickly approved by the Office for Civilian Defense in Washington, proved a model of its kind and has since been recognized as such throughout the industry.

Now, thanks to the valuable work of Chairman Allan in further spreading the gospel of plant protection, the code is being used as the basis for similar codes in a number of vital defense areas. "Jim" Allan has been called on many times to discuss methods of plant protection before executives of individual plants, as well as before officials of important civic bodies. He now reports that the State of Wisconsin, Citizens' Defense Corps, has adopted a code based primarily on the A.F.A. work, and soon will distribute it to all industrial plants in that state.

Recently "Jim" Allan was instrumental in formulating a code for the Chicago Metropolitan area, and a definite, practical method of following it up. A plant protection inspection report in the form of a questionnaire, reproduced on the opposite page, has been prepared and will be filled out by city firemen in personal contacts with ranking executives of each industrial plant in the area. These questionnaires then will form an accurate basis for checking on the facilities of each plant, with a view to their prompt correction.

Thus the A.F.A. code bids fair to form a basis, as well it might, for a nationwide formula for plant protection in wartime, the need for which has been greatly emphasized by the recent F.B.I. round-up of spies and potential saboteurs.

1942 Brazilian Paper Author Joins U. S. Navy

H. A. HUNNICUTT, formerly associated with Industrias Chimicas Brasileiras, Soa Paulo, Brazil, and a member of the South American foundry delegation at the 1942 convention of A.F.A., has been appointed Lieutenant, Junior Grade, in the United States Navy, and now is assigned to the office of the Navy Department, Washington, D. C. Those who attended the Cleveland convention may recall that Mr. Hunnicutt presented there, at the special Western Hemisphere Foundry Conference session, a paper dealing with the Brazilian castings industry.

Mr. Hunnicutt was connected with the Brazilian organization for a number of years, as metallurgical engineer. It has since

H. A. Hunnicutt

been learned that he had returned to the United States at the time of the 1942 A.F.A. Convention with the specific intention of entering the Navy. His years of residence in Brazil enabled him to present a very interesting paper outlining the methods and needs of the foundries in that and other South American countries.

Retired "Old Timer," Jas. Millar, Dies at 67

JAMES MILLAR, active in the foundry industry for over half a century, and for 35 years general superintendent, Buffalo Foundry & Machine Co., Buffalo, N. Y., died June 29 at his Buffalo home. Born in Glasgow, Scotland, in 1875, Mr. Millar served his molder's apprenticeship in Scotland and worked in leading marine shops on the Clyde river, coming to the United States in 1900. He worked in a number of the larger foundries in this country and was known for his proficiency in making large and difficult castings. In 1937 he retired from the Buffalo concern and devoted his remaining years to the raising and flying of homing pigeons, at which he was an expert.

Tin Bronze Specification Changed — A.S.T.M. Tentative Specifications for Tin Bronze and Leaded Tin Bronze Sand Castings A 143-41T have been changed. Specifically, the copper content has been changed to a minimum of 86.50 per cent with no maximum, and the maximum iron and phosphorus percentages allowable have been increased to 0.25 and 0.05 per cent, respectively. In addition, the minimum elongation requirement for Alloy 2A now is 22 per cent instead of 20 per cent.

New Members

Thirteen may be an unlucky number for some folks, but it proved lucky for the Northern California Chapter this time—leading this month's New Member list with 13, all from one foundry company.

(June 16 to July 15, 1942)

Conversions

Sustaining from Company

Caterpillar Tractor Co., Peoria, Ill. (M. J. Gregory, Factory Mgr.)
Crane, Limited, Montreal, Que., Canada (W. Baxter, Gen. Supt.)
Snyder Foundry Supply Co., Los Angeles, Calif. (George W. Effinger, Vice Pres.)

Company from Personal

Badger Malleable & Mfg. Co., South Milwaukee, Wis. (A. J. Ricker, Pres.)
Canada Metal Co., Ltd., Toronto, Ont., Canada (James Dalby, Supt. Fdry. Div.)
Hart-Carter Co., Minneapolis, Minn. (O. K. Mayhew, Superintendent)

Chesapeake Chapter

Lloyd G. Jordan, Molder, Norfolk Navy Yard Foundry, Portsmouth, Va.
Robert E. Lyons, Bureau of Ships, Navy Dept., Washington, D. C.

Chicago Chapter

Paul J. Bauman, Plant Supt., National Bearing Metals Corp., Chicago, Ill.
Eugene Mannion, Beardsley & Piper Co., Chicago
Neil Rohn, Asst. Supt., National Bearing Metals Corp., Chicago

Cincinnati Chapter

John M. Gardner, Jr., Foundry Practice Unit, Wright Aeronautical Corp., Lockland, Ohio
E. N. Wirthlin, Pres., The Wirthlin-Mann Co., Cincinnati, Ohio

Detroit Chapter

Ford Airplane Apprentice School, Willow Run Plant, Ford Motor Co., Willow Run, Mich.
*F. C. Williams, Inc., Dearborn, Mich. (Francis C. Williams, Pres.)
Earl E. Woodliff, Foundry Sand Service Engineering Co., Detroit, Mich.

Eastern Canada and Newfoundland Chapter

C. F. Pascoe, Works Mgr., Canadian Car & Foundry Co., Ltd., Longue Pointe Works, Montreal, Que.
*The Plessisville Foundry, Plessisville, Que., Canada (Lucien Dancause, Supt.)

Metropolitan Chapter

*Universal Foundry Company, Inc., Paterson, N. J. (Louis D'Annunzio, Jr., Pres.)

Northeastern Ohio Chapter

G. C. Brewster, "L" Plant Tech. Dept., Aluminum Co. of America, Cleveland, Ohio

Northern California Chapter

Leo Belletti, Appr. Molder, Enterprise Engine & Foundry Co., So. San Francisco, Calif.
Ernest W. Boynton, Molder, Enterprise Engine & Foundry Co., So. San Francisco, Calif.
James V. Farace, Cleaning Room Foreman, Enterprise Engine & Foundry Co., So. San Francisco, Calif.
George E. Fogarty, Foreman, Enterprise Engine & Foundry Co., So. San Francisco, Calif.
Edward High, Appr. Coremaker, Enterprise Engine & Foundry Co., So. San Francisco, Calif.
Arvid D. Hoxie, Coremaker, Enterprise Engine & Foundry Co., So. San Francisco, Calif.
Duane E. Johnson, Appr. Molder, Enterprise Engine & Foundry Co., So. San Francisco, Calif.
Robert B. Johnson, Molder, Enterprise Engine & Foundry Co., So. San Francisco, Calif.
Rudolph E. Kelly, Coremaker, Enterprise Engine & Foundry Co., So. San Francisco, Calif.
Vladimir P. Kopeikin, Cleaning Room Foreman, Enterprise Engine & Foundry Co., So. San Francisco, California
R. O. Kramer, Asst. Plant Mgr., Enterprise Engine & Foundry Co., So. San Francisco, Calif.
Hugh F. Prior, Asst. Melter, Enterprise Engine & Foundry Co, So. San Francisco, Calif.
Fred Alvin Steele, Supv. Coremaker, Enterprise Engine & Foundry Co., So. San Francisco, Calif.

Ontario Chapter

Benton Dixon, Sales, Secy., Dominion Wheel & Foundries, Ltd., Toronto, Ont., Canada
E. J. Langan, Plant Mgr., Canada Metal Co., Ltd., Toronto, Ont., Canada
George W. McCrae, Mech. Engr., John McCrae Machine & Foundries Co., Lindsay, Ont., Canada

Philadelphia Chapter

Rudolph R. Ashman, Molder Foreman, Bethlehem Steel Co., Bethlehem, Pa.
H. W. Brown, Dist. Mgr., W. W. Sly Mfg. Co., Philadelphia, Pa.

Quad-City Chapter

*Canfield and Clark, Dallas City, Ill. (Don Clark, Co-Partner)
Charles A. Davis, Purch. Dept. Engr., Caterpillar Tractor Co., Peoria, Ill.

St. Louis District Chapter

E. Eugene Ballard, National Bearing Metals Co., St. Louis, Mo.

Southern California Chapter

W. A. Dougherty, Mgr., Universal Cast Iron Pipe & Fittings Co., Los Angeles, Calif.
Robert E. Popperwell, Patt. Shop Foreman, Reliable Iron Foundry, Los Angeles

Western New York Chapter

John T. Domanski, Core Room Foreman, Worthington Pump & Machinery Corp., Buffalo, N. Y.
*Medina Stamping & Machine Co., Inc., Medina, N. Y. (Leo E. Collins, Pres.)
*National Gypsum Company, Buffalo, N. Y. (R. R. Rychener, Industrial Sales Div.)
H. Oliver Pels, Brass Fdry. Foreman, Harrison Radiator Div., G.M.C., Lockport, N. Y.
Leslie C. Thellemann, Secy., Inter-Allied Foundries of New York State, Buffalo, N. Y.

Wisconsin Chapter

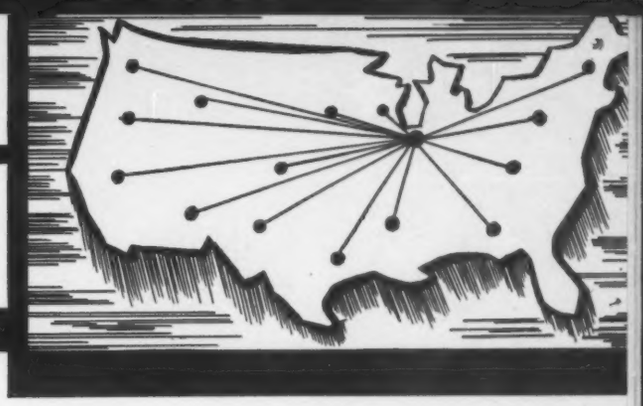
Dell R. Dennis, Patt. Foreman, Allis-Chalmers Mfg. Co., West Allis, Wis.
Robert J. Dillon, Lieutenant, U. S. N. R., Asst. to Resident Inspector of Naval Materials, U. S. N., Milwaukee, Wis.
Clemens Kolinski, Core Foreman, Allis-Chalmers Mfg. Co., West Allis, Wis.
Frank A. Myers, Facility Engr., War Department, Production Service Division, Chicago Ordnance District, Milwaukee Sub-Office, Milwaukee, Wis.
O. T. Nelson, Bldg. Engr., Industrial Comission of Wisconsin, Madison, Wis.
Arthur J. Schwai, Inspector, Army Air Force, Milwaukee, Wis.

Outside of Chapter

*Netherton Iron Works, Holly Hall, Worchestershire, England (O. F. Grazebrook, Mgr. Dir.)
*The Charles Parker Co., Meriden, Conn. (Charles S. Parker, Pres.)
Public Library of South Australia, Adelaide, South Australia
Henry H. York & Co., Pty. Ltd., Sydney, Australia

*Company Member.

Chapter Activities



Southern California's Final Season Meeting

By E. M. Hagener,* Los Angeles, Calif.

WITH the emphasis on local defense, the Southern California chapter held its final meeting of the season June 16 at the Clark hotel, Los Angeles. Officers who served during the past year, headed by President B. G. Emmett, Los Angeles Steel Casting Co., Los Angeles, presented their reports, and newly elected officers and directors were installed.

Newly elected Chairman Earl Anderson, Enterprise Iron Work, Los Angeles, then took the chair and introduced the first guest speaker, Lon Ashman, who gave a brief talk on the pig iron situation on the Pacific Coast. Announcement also was made that the summer party would be held Saturday, July 25.

Guest speaker of the evening was C. B. Tibbetts, president, Los Angeles Steel Casting Co., Ltd., and president of the Los Angeles Chamber of Commerce. Mr. Tibbetts discussed plant protection with special emphasis on the foundry problems in meeting blackout conditions on the Pacific Coast. He stated that plans now are being formulated to the end that practically all industries in Southern California would be able to offer air-raid protection for their employees, and also would be able to assist in the camouflage blackout program. Some discussion regarding civilian defense operations followed.

*General Metals Corp., Los Angeles, and Secretary, Southern California chapter.

Cincinnati Has Outing And Elects Directors

By Henry M. Wood,* Cincinnati, Ohio

MEMBERS and guests of the Cincinnati chapter held their annual stag outing and election of directors June 16 at the Hyde Park Golf and Country club, with fully 200 present. The afternoon was given over to golf and a baseball game between the Foundrymen and Vendors (which, incidentally, the Foundrymen won, 17-3, the game being called at the end of six innings).

Following a buffet dinner, Chairman W. M. Ball, Jr., Edna Brass Mfg. Co., presided at the election of *Directors*, the following being selected to serve for 3 years: William W. Beiser, Reliance Foundry Co.; Wm. Gilbert, Jr., Buckeye Foundry Co.; David L. Longeuville, Wright Aeronautical Corp.; William A. Rengering, Cincinnati Milling Machine Co.

Previously elected *Directors*: W. M. Ball, Jr.; L. A. Gosiger, S. Obermayer Co.; Charles R. Hilb, H. Kramer & Co.; H. W. Kautz, Cincinnati Milling Machine Co.; E. H. King, Hill & Griffith Co.; Martin F. Milligan, The Lunkenheimer Co.; J. W. Nichols, Ingersoll-Rand Co.; Henry M. Wood.

*W. W. Sly Mfg. Co., and Secretary, Cincinnati chapter.

Cement Molding Topic Of New England Group

By Merton A. Hosmer,* Boston, Mass.

EIGHTY members and guests of the New England Foundrymen's Association gathered at the Engineers Club, Boston, on June 10 for their regular meeting, and to hear an interesting talk on cement molding in the foundry. Presiding officer was President Raymond F. Meader, Whitin Machine Works.

Charles A. Sleicher, New England Butt Co., Providence, R. I.,

*Hunt-Spiller Mfg. Corp., and Reporter, New England Foundrymen's Association.

Here and there at the annual stag party of the Cincinnati Chapter, June 16. Top Row, Left to Right: (1) "Lineup" for the baseball game, Foundrymen vs. Vendors; (2) Geo. Black, L. Naberhaus, Gil Bohn, Dick Rowe; (3) and (4) "Play Ball." Bottom Row, Left to Right: (1) Don Mauer, J. W. Nichols, L. A. Gosiger, Billy Gilbert; (2) F. Lloyd, R. Haskell, J. C. Gysin, W. Appel, H. Oberhelman; (3) C. Milligan, Russ Whitehead; (4) Wm. Beiser, F. Hutchinson, C. H. Gysin, Hy Chisholm; (5) H. Greek, R. Schlagle, Chas. E. Koehler, Earl H. Thompson.

(Photos courtesy Ed. H. King, Hill & Griffith Co.)

(Photos courtesy Sterling Farmer, Sand Products Corp.)

Portrait of an A.F.A. Chapter at its annual summer outing . . . the Northeastern Ohio Chapter taking time off from war production work for a relaxing day in the open, including baseball, golf, kibitzing, and general sociability. Bottom right—Jack Tressler, Hickman Williams & Co., Cleveland, president of the chapter, reads a few announcements.

was the guest speaker, who presented a paper on the use of cement in molding castings, particularly large castings such as lathe beds and bases. Some of the advantages claimed for the process were speed, quality of castings, economy, and relief of crowded core or mold drying ovens. The mixture discussed by the speaker consisted of 89 per cent sand and 11 per cent cement, by volume.

Mr. Sleicher presented details for molding with cement, stating that any good quick-drying cement is satisfactory, molds being dried for 72 hours at 70 degrees Fahr. regardless of size of mold. The mold surface, he stated, usually is given several coats of blacking. Large sections are reinforced to prevent cracking at corners.

During the evening the chapter paid tribute to Frederick H. Franklin, who died recently, through a resolution prepared by a special Committee on Resolution headed by R. F. Harrington, Hunt-Spiller Mfg. Corp.

Blackouts Forgotten at Northern California's Big Annual Meeting

By George L. Kennard,* San Francisco, California

A RECORD attendance of 166 members, ladies and guests of the Northern California chapter celebrated the annual meeting, held June 12 at the Hotel Claremont, San Francisco. Retiring Chairman E. M. Welch, American Manganese Steel Co., Oakland, performed the duties of master of ceremonies in fine style. In appreciation of his service during the past year, he was presented with a gift on behalf of the chapter. Past Chairman Ivan L. Johnson, Jr., Pacific Steel Casting Co., Berkeley, made the presentation.

The real business of the evening was the election of new officers and directors, the report of the Nominating Committee being presented by S. D. Russell, Phoenix Iron Works, Oakland. The slate was accepted unanimously, the following being elected for the coming year:

Chairman, F. A. Mainzer, Pacific Brass Foundry of San Francisco, San Francisco; *Vice-Chairman*, H. A. Bossi, H. C. Macaulay Foundry Co., Berkeley; *Secretary-Treasurer*, George L. Kennard; *Directors* (2 year terms): Fred L. DeSanno, DeSanno Foundry & Machine Co., Oakland; J. F. Driscoll, Rincon Iron

*Northern California Foundrymen's Institute, and Secretary-Treasurer, Northern California chapter.

& Brass Foundry, San Francisco; R. C. Noah, San Francisco Stove Works, San Francisco; E. M. Welch, American Manganese Steel Co., Oakland.

Directors continuing to serve: Howard I. Detro, American Radiator & Standard Sanitary Corp., Richmond; Ivan L. Johnson; S. D. Russell; Richard Vosbrink, Berkeley Pattern Works, Berkeley.

Following the elections the new officers and directors gave short talks of acceptance, after which dancing became the sole activity until a satisfactorily late hour, without fear of blackout problems.

Officials who participated in the program when the Navy presented the Navy "E" flag to the Howard Foundry Co., Chicago. Left to right—A. P. Rankin, Manitowoc Shipbuilding Corp., Manitowoc, Wis.; Rear Admiral W. C. Watts, Washington, D. C.; F. C. Howard, vice president of the Howard organization; Lt. Comm. W. R. Ignatius, Manitowoc.

Howard Foundry Wins Navy "E" for Its Non-Ferrous Production

ONCE again the importance of the foundry in our war program was emphasized when, on July 9, the Navy's Bureau of Ordnance presented the famed Navy 'E" flag for excellence in ordnance production to the Howard Foundry Co., Chicago. Thus, the Howard company, with its plants in Chicago and Aurora, became one of the first exclusive non-ferrous foundries in the country to receive the coveted pennant.

Presentation was made at a special flag-raising ceremony at the plant, attended by some 1,200 company executives, Naval officers, city officials and employees and their families. Rear Admiral W. C. Watts (Retd.), Washington, D. C., presented the pennant on behalf of the Navy, and praised the company for its quality and production record in turning out submarine shipbuilding parts. A. P. Rankin, Manitowoc Shipbuilding Corp., Manitowoc, Wis., acted as master of ceremonies, introducing the speakers and officials present. These included F. C. McGuire, representing Chicago; Lt. Commander W. R. Ignatius, Manitowoc, and Lt. Commander G. C. Weber, Chicago.

The flag was received for the company by F. C. Howard, vice president, who pledged the Navy even greater production efforts in the future, with emphasis on quality and speed. He stated that the Howard firm, producers of non-ferrous castings for the past 25 years, now is in virtually 100 per cent war production.

The colorful program was highlighted by the music from the U. S. Naval Training School Band, stationed on Municipal Pier, Chicago. Employees of the firm were represented on the speakers' platform by the four oldest workers.

Flag raising ceremony at the Howard Foundry Co., Chicago, when the non-ferrous castings producer received the coveted Navy "E" flag for quality and production of naval ordnance materials.

Dimensions of Cast Iron Test Specimen Changed—The diameter of the cast iron tensile specimen, contained in A.S.T.M. Specifications A 48-41, for such specimens machined from 1.2-in. diameter bars, has been changed from 0.800-in. to 0.750-in. The change is said not to affect the strength test results and eliminates the tendency toward shoulder breaks sometimes encountered in testing higher strength classes of irons with section of 0.800-in. diameter.

Get behind the voluntary War bond purchase program — "*A Dime for Every Dollar Every Pay Day.*"

Abstracts

NOTE: The following references to articles dealing with the many phases of the foundry industry, have been prepared by the staff of *American Foundryman*, from current technical and trade publications.

When copies of the complete articles are desired, photostat copies may be obtained from the Engineering Societies Library, 29 W. 39th Street, New York, New York.

Aluminum Castings

POROSITY. *(See Non-Ferrous.)*

Aluminum-Magnesium

(See Non-Ferrous.)

Blast Furnace

AIR CONDITIONED. *(See Furnaces.)*

Bombs

STEEL. *(See Steel.)*

Cast Bronzes

TIN ALTERNATIVES. *(See Non-Ferrous.)*

Cast Iron

CRANKSHAFTS. *"The Manufacture of Crankshafts in High-Duty Cast Iron,"* by E. M. Currie and R. B. Templeton, *Foundry Trade Journal,* vol. 66, No. 1332, February 26, 1942, pp.133-135, and vol. 66, No. 1333, March 5, 1942, pp. 149-151. Object of the paper is to call the attention of engineers and designers to the possibilities of substituting high-duty cast iron castings for steel forgings, and to present details of results obtained from experimental trials by engine builders, as well as results obtained by various manufacturers in replacing steel forgings with castings in crankshaft production. Extensive research on the suitability of modern high-duty cast irons for crankshafts have been conducted by the authors, tending to show that such irons have certain physical properties which make them entirely suitable. Properties of cast iron of importance to crankshaft designers are given as: Tensile strength, fatigue strength, notch sensitivity, torsion strength, damping capacity, and wear resistance. The effect of design on these properties is given in detail. Foundry practice is stressed as of utmost importance, it being stated that most cast crankshaft failures have been due largely to some factor of design which could not be modified or was not modified to meet foundry recommendations, especially web design. In general, it is stated that the majority of cast crankshaft failures under test have been due to faulty web design. In the author's opinion, developing a proper appreciation of "design strength" is the only means of improving the fatigue strength of cast crankshafts, and design based on these lines will simplify the metallurgical problem and insure sound castings.

CUPOLA OPERATION. *"Cupolas and Materials,"* by D. J. Reese, *Canadian Metals and Metallurgical Industries,* vol. 5, No. 6, June 1942, pp. 160-163. Factors which experience shows are essential to outstanding cupola operation in cast iron melting are given and discussed: (1) Do not overemphasize importance of tuyeres; (2) Proportion size of materials charged to cupola diameter, and use weights of fuel and metal charges based on reasoning; (3) Be sure the charging gang and cupola tender have the right equipment and materials, properly placed; (4) There is no substitute for accurate weighing of the coke charge; (5) Use correct weight fuel charge; (6) Weight of the coke charge depends on the actual fuel ratio and not the apparent fuel ratio; (7) Relationship between metal melting rate and air flow is important; (8) A melting rate of 25 lbs. per sq. ft. or over is better than a rate between 10 and 25 lbs.; (9) Method of tapping the cupola is important; (10) Metal may be altered in the ladle with ladle inoculants; (11) Metal should be transferred from the furnace to the mold in shortest practical time; (2) Molds should be filled as quickly as possible; (14) The insulating effect of a mold will have a bearing on the properties of the iron.

LADLE PREHEATING. *(See Pouring Practice.)*

PRESSURE CASTINGS. *"Gating and Risering for Pressure Work,"* by H. H. Judson, *Canadian Metals and Metallurgical Industries,* vol. 5, No. 5, May 1942, pp. 143-144. Digest of paper dealing with elimination of risers in avoiding spongy or open-grained spots under risers in casting centrifugal pump casings and reciprocating pump cylinders and valve boxes. Castings weighed from 1000-2000 lbs., sections varying from 5/8 in. to 3½ in. Spongy spots were encountered occasionally apparently as the result of molten metal purging back into the risers shortly after pouring was completed, when using hard, rigid dry sand molds. When risers were eliminated entirely, and flow-offs too small to provide any feeding action were employed, the spongy spots diasappeared. Details of the foundry practice used in making the pressure castings are given.

Core

OVENS. *"Modernization of Core Baking Ovens,"* by Wm. J. Shore, *Industrial Heating,* vol. 9, No. 6, June 1942, pp. 774, 777-781, 796. Today's demand for better castings and uniform product, in the face of stricter specifications, calls for modern core baking practice. Modernization of a core oven in continuous use for over 50 years in a brass foundry is described. The oven measured 8x8x10 ft. inside, with three 9-in. brick sidewalls, sheet metal front doors lined with 2 in. of magnesia, and a roof of 2 in. cast iron slabs with a 5 in. layer of firebrick on top. First the ceiling and three walls were covered with 2 in. of insulating material. Gas heater was top installed, with recirculating fan to provide even distribution of heat throughout the oven. Excess air was discharged by static pressure through four bottom outlets. Temperature control was obtained by thermostat equipment in the exhaust stream, oven temperature being regulated between 350 and 375°F. It is stated that the cost of converting old brick core ovens to modern types of fuel equipment and control should average about $1.50 per cu. ft. of oven area. A fair operating cost for fuel and electricity is given as 8c per hour, or 88c per daily batch.

Cupola

(See Cast Iron.)

MOISTURE CONTROL. *(See Furnaces.)*

Furnaces

BLAST. *"Air-Conditioned Blast," Foundry Trade Journal,* vol. 66, No. 1339, April 16, 1942, p. 250. Digest of article in *Blast Furnace and Steel Plant* by E. K. Miller describing a pre-compression chilled water system installed on a large blast furnace at the Aliquippa Works, Jones & Laughlin Steel Corp. Comparative data is presented on the control of moisture with and without blast conditioning.

Gating and Risering

PRESSURE CASTINGS *(See Cast Iron.)*

Hot Tears

(See Steel.)

Magnesium

ALLOYS. *(See Non-Ferrous.)*

Non-Ferrous

ALUMINUM CASTINGS. *"Porosity in Aluminum Castings,"* by William Wilson, Jr., *The Metal Industry,* vol. 60, No. 11, March 13, 1942, pp. 191-192. Causes and elimination of porosity frequently are not clearly understood. Experience with aluminum castings shows that causes of porosity are of four general types: Metal, gating, trapped air and gas, and shrinkage. A method of eliminating porosity in the metal is given. Porosity caused by improper gating is characterized by holes in various parts of the same casting. Remedies are given, involving consideraton of the size and shape of the casting, characteristics of the metal, and pouring temperature. Porosity caused by trapped air and gas in the mold is indicated by small holes in the cope side of the casting, and is directly associated with sand permeability, and venting. Shrinkage porosity is caused by variation in wall thickness, insufficient feed to heavy sections, lack of pressure. It is advocated that porosity first be classified as being one of the four general types, the various elements in that class then being studied for elimination of the defect.

ALUMINUM-MAGNESIUM. *"Aluminum-Magnesium Alloys—Resistance to Chemical Attack,"* by L. J. Benson and R. B.

Mears, *The Metal Industry,* vol. 60, No. 23, June 5, 1942, pp. 380-382. Aluminum-base alloys containing varying amounts of magnesium not only possess lightness inherent in both metals, but also show marked resistance to action of alkaline media. Following previous experiments on such alloys when exposed to sodium carbonate solutions, the authors present test data involving corrosion by solutions of sodium hydroxide and sulphuric acid, all tests being conducted at 31° C. (87.8° F.). Results showed that (a) solutions of sodium hydroxide or sulphuric acid below 0.1 per cent do not appreciably attack high purity aluminum and aluminum-magnesium alloys; (b) with 4 per cent magnesium, aluminum-magnesium alloys are equally resistant to 0.1 and 1 per cent sodium hydroxide as alloys containing less magnesium; (c) alloys with 4 per cent magnesium are less resistant to 0.1 and 1 per cent sulphuric acid than alloys with less magnesium content; (d) addition of sodium dichromate to a 10 per cent sulphuric acid accelerated attack somewhat, and similar addition to a sulphuric acid-sodium chloride solution increased acceleration of attack greatly.

MAGNESIUM ALLOYS. *"The Alloys of Magnesium,"* by F. A. Fox, *The Metal Industry,* vol. 60, No. 13, March 27, 1942, pp. 220, 223; vol. 60, No. 14, April 3, 1942, pp. 239-241; and vol. 60, No. 15, April 10, 1942, pp. 260-262. Magnesium and its alloys are used for two general purposes today: (a) For engineering applications where lightness or high specific tenacity is required, using alloys both in cast and wrought form; (b) For pyrotechnic and similar uses, in solid or powder form, as for incendiary bombs, in England such alloys containing about 5 per cent aluminum with small amounts of zinc and manganese. Specifications of commercial magnesium casting alloys used during the past 15 years are compared in tabular form, differences in mechanical properties being examined in terms of British, German and American test bars. Physical properties are discussed, including corrosion resistance, influence of impurities, and soundness. Similar data are tabulated for commercial magnesium wrought alloys suitable for sheet, extrusion and forging, and their heat treatment is discussed. Micro-structural features of magnesium alloys are given, also data on surface protection, deep drawing, and machinability. Applications of the alloys to aircraft, including German types of planes, are presented.

TIN CONSERVATION. *"Tin Conservation —Alternatives to Tin in Cast Bronzes," Canadian Metals and Metallurgical Industries,* vol. 5, No. 4, April 1942, pp. 98-101, 107, 123. A symposium digesting information presented at a special A.S.M. meeting on tin substitutes, held March 23 in Montreal, and an A.F.A. meeting held April 10 at Toronto. The tin emergency is outlined and possibilities discussed for the use of alternatives to tin in the tin bronzes, through use of tin-free bronzes such as the manganese bronzes, aluminum bronzes, and silicon bronzes. The use of nickel as a partial substitute for tin also is discussed.

Pouring Practice

LADLE PREHEATING. *"An Improved Method for Drying and Preheating Ladles," Iron and Steel,* vol. 15, No. 9, May 1942, pp. 272-273. Ladles usually are dried and preheated in one of several ways: (1) By lighting a fire in the ladle; (2) inverting ladle over a fire; (3) laying ladle on its side and applying a gas or oil burner horizontally; (4) keeping ladle upright and applying a gas or oil burner vertically downward. Preheating equipment is described consisting of a flat shield covered on the inside with plastic refractory, which is lowered down in contact with the ladle top. The device is fired by producer gas (it is claimed equally applicable for oil firing), and is fitted with two ventilating chimneys. Sufficient air is supplied to the outer jacket to keep the flame down inside the ladle, intensity of flame being controlled by adjusting the central air supply. The method also has been applied to drying and preheating drum type bogies used for molten cast iron.

Steel

BOMBS. *"The Foundry Industry and Air Warfare," Foundry Trade Journal,* vol. 66, No. 1338, April 9, 1942, p. 229, and vol. 66, No. 1339. April 16, 1942, pp. 247-248. In the manufacture of aerial bombs in England, some are made flat, some nose-up, others nose-down. This paper describes the manufacture of 500-lb. bombs cast nose down by hand methods, although the author states the practice is suitable also for production work. A metal pattern is used, made in two parts of duralumin or the like, about 1 in. thick. The corebox, made of the same material, is in three sections. The core barrel is made of 2⅜ in. diameter mild steel tubing, perforated with ⅜ in. holes, wrapped with coarse straw rope, and fitted with a ferrule on the end. In the pouring operation, this ferrule becomes integral with the casting nose and is later machined out. Bombs are molded two at a time, cores being centered at the bottom by means of the ferrule on the core barrel, and a clay ring in the mold bottom. Feeding is by two horn runners. Although the bomb is a two-part job, it is three-part molded. The mold assembly is illustrated in Fig. 1, below.

HOT TEARS. *"Tearing in Castings—Influence of Mold Friction,"* by Prof. J. H. Andrew and H. T. Protheroe, *Iron and Steel,* vol. 15, No. 10, May 14, 1942, pp. 315-318. Hot tearing is usually attributed to the resistance offered by the sand to the contraction of the casting, with the result that such methods as digging sand away from runners and feeder heads, and collapsible cores, are employed. Data are given on a large number of tests which indicate that hot tearing is due rather to the resistance offered to contraction by the bulk of sand than to the nature of the sand. When steel castings are stripped from the mold a thin layer of burned sand is observed between the face of the casting and the main body of sand, this layer being very friable and easily removed. Since this sand has no strength, it is considered unlikely that it offers any resistance to the contractional movement of the casting. It is felt that the temperature at the crucial moment during contraction will decide where the casting tears, and in every test this was in the hottest region, near the runner. As to temperature, data indicated that tearing occurs somewhere near the solidification temperature. It is shown that, provided one runner is set at a sloping angle, hot tearing will not occur.

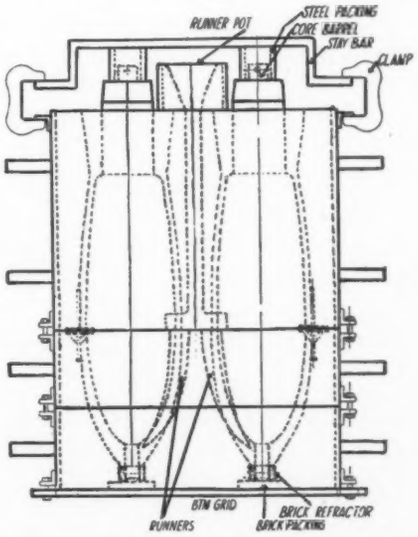


Fig. 1—Details of mold assembly in English foundry for casting two 500-pound aerial bombs, cast nose-down. Three core boxes are used, two for the bottom half, one for the top half. The assembly shows method of centering and setting cores, feeding head, and horn runners.

LADLE PREHEATING. *(See Pouring Practice.)*

TEMPERATURE MEASUREMENTS. *"Liquid Steel Temperatures," Foundry Trade Journal,* vol. 66, No. 1335, March 19, 1942, pp. 183-184, and vol. 66, No. 1336, April 2, 1942, pp. 207-208. Extracts from third report of the Liquid Steel Temperature Sub-Committee of the Committee on Heterogeneity of Steel Ingots, British Iron and Steel Institute, covering work carried out in Sheffield during past two years on the quick-immersion technique for measuring temperature of liquid steel by means of a platinum thermocouple. Report is divided into two sections. Sec. I presents general comments on design of the quick-immersion thermocouple, temperature distribution and control in furnace and ladle, emissivity and optical pyrometry, and an outline of the sub-committee's program of research. Sec. II describes recent experimental work with the quick-immersion thermocouple in several steel plants, covering apparatus for large open-hearth and electric furnaces, and apparatus for ladle and trough.

Testing

STEEL TEMPERATURE. *(See Steel.)*

WEAR. *"Automatic Autographic Wear-Measuring Device,"* by C. W. Muhlenbruch, *Mechanical Engineering,* vol. 64, No. 4, April 1942, pp. 289-290. In making comparative wear tests of bearing materials under similar conditions of pressure, lubrication, velocity, surface finish, and other complex and numerous variables encountered in such tests, the amount of specimen material displaced by wear or plastic flow may be obtained by measuring the deflection of a combination loading arm and "wear" magnifying lever, or by removing the specimen from its holder and noting the change in thickness. Readings are taken at regular intervals of time to give one form of wear-time relationship. Description is given of an apparatus which automatically produces such a displacement-time diagram with results that vary from measured values by a maximum of 4 per cent.

Tin

CONSERVATION. *(See Non-Ferrous.)*

Tin Bronzes

TIN CONSERVATION. *(See Non-Ferrous.)*

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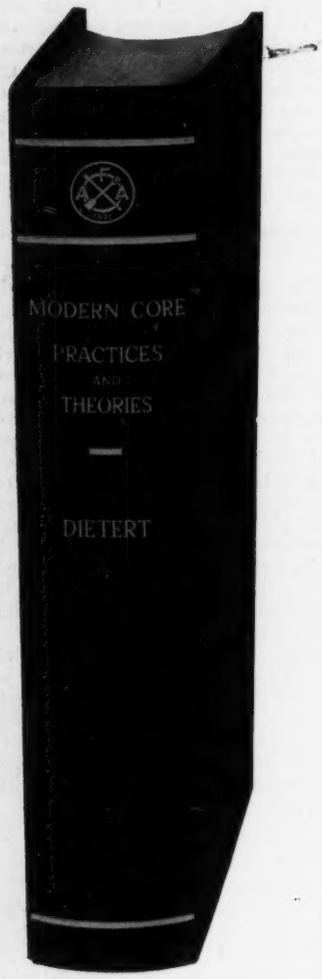

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